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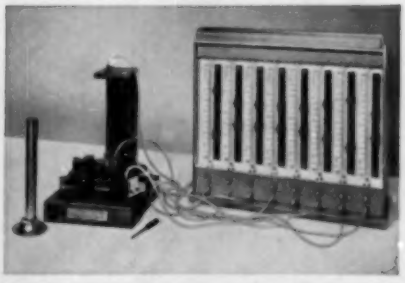

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(Left to right) Dr. John Bardeen*, Dr. William Shockley* and Dr. Walter H. Brattain, shown at Bell Telephone Laboratories in 1948 with apparatus used in the early investigations which led to the invention of the transistor.

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Drs. John Bardeen, Walter H. Brattain and William Shockley are honored for accomplishments at the Laboratories

The 1956 Nobel Prize in Physics has been awarded to the three inventors of the transistor, for "investigations on semiconductors and the discovery of the transistor effect."

They made their revolutionary contribution to electronics while working at Bell Telephone Laboratories in Murray Hill, N. J. Discovery of the transistor was announced in 1948. Bell Laboratories is proud to have been able to provide the environment for this great achievement.

This is the second Nobel Prize awarded to Bell Telephone Laboratories scientists. In 1937 Dr. C. J. Davisson shared a Nobel Prize for his discovery of electron diffraction.

Such achievements reflect honor on all the scientists and engineers who work at Bell Telephone Laboratories. These men, doing research and development in a wide variety of fields, are contributing every day to the improvement of communications in America.

**Dr. Bardeen is now with the University of Illinois, and Dr. Shockley is with the Shockley Semiconductor Laboratory of Beckman Instruments, Inc., Calif.*

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Quality Control

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From the President's Desk

An Important Message

Dear Member:

After careful consideration, your Board of Directors voted on November 17, 1956 to recommend, for membership approval, amendments to the constitution involving modest increases in Society dues. For Members, the dues would be increased from $10 to $12, and for Senior Members and Fellows, from $12 to $15, effective July 1, 1957. The amendments will be proposed at the time of the annual postal ballot in April of this year.

The action of the Board of Directors followed a review of the financial position of the Society and a study of our dues structure in relation to our needs and our income from other sources. In this connection, several Section officers have been most helpful in providing information as to how we might best meet our increasing income requirements. Many excellent suggestions were received, in addition to dues change proposals, and these will receive further attention in connection with long range planning of Society operations.

For several years it has been apparent to the Officers that to keep pace with the increasing expense of improving and expanding our services to members, additional income would be needed. It was felt that efforts should first be made to effect economies in operation, consistent with these improved services, and to increase our publications income before considering a dues increase. As you know, consolidation of our several offices took place last year and very real progress has been made in our staff functioning. Thanks to the splendid work of many members of the Society, our advertising program has moved forward substantially, such that it now appears that the transition from a six-issue to a twelve-issue journal has been successfully effected. Likewise, our progress in the library subscription and technical literature areas has been satisfactory.

It is believed that further efforts can still be made along these same lines which will stimulate additional income, and to this end an Administrative Secretary has been employed to provide effective management and business guidance to our affairs. The score and magnitude of this work, for sound operation, are simply beyond the efforts which the Officers and Directors of the Society can devote on a volunteer basis to our growing organization and our expanding influence.

In spite of all these efforts, for the past two years the operating expenses of the Society have slightly exceeded income from membership dues and from publications. While our over-all financial position is good, we obviously can not continue indefinitely deficit financing of normal operations. The Officers and Directors feel that we must now look to increased member dues as a source of additional revenue, a step that has already been taken in recent years by most technical societies. The proposed increases will, it is confidently expected, enable the Society to carry on its expanding program, improve still further its service to members, and enhance the standing of the quality control profession.

The broad financial aspects of Society operation are matters that should be of direct interest to you as a member of ASQC. It is planned to provide such information for you in forthcoming issues of *Industrial Quality Control*.

On behalf of the Officers and Directors of the Society, I hope that the dues increase proposal which they believe was made in your best interests as a member of ASQC, will receive your wholehearted support.

Dale L. Lobaugh

Sampling Inspection by Variables With No Calculations*

HERMAN CHERNOFF, GERALD J. LIEBERMAN

Stanford University, Stanford, Calif.

Introduction

Most industrial applications of acceptance sampling today are by attributes, and will probably continue in this way. Nevertheless, the increase in the use of modern statistical techniques in industry has resulted in the more widespread use of sampling inspection by variables. The advantages of sampling inspection by variables are well known. For example, for a given operating characteristic curve (O.C. curve), smaller samples may be used with variables than with attributes to insure this specified protection. On the other hand, the disadvantages of sampling inspection by variables are also well known. Perhaps the two most important of these are (1) the increased clerical costs of recording the data and making relatively (compared to attributes) difficult computations, and (2) the operating characteristic curves depend heavily on the assumption that the form of the underlying frequency distribution of the quality characteristic is normal. This assumption is often difficult to evaluate.

The purpose of this article is to present a graphical procedure for sampling inspection by variables which involves no computations and which also gives a check on the assumption of normality. This procedure will be referred to as "No Calc." in the ensuing sections. The results are only approximate and should be considered to be a "quick and dirty" technique and used where such procedures are tolerable. Although the approximations are good, "No Calc." is not a replacement for the usual variables procedures when a contract between two parties exists and calls for inspection by variables.

"No Calc." Procedure

Prepare a sheet of normal probability paper‡ labelling the abscissa (horizontal axis) to represent a percentage, p, between 0 and 100, and the ordinate (vertical axis) to represent the observation scale. Draw a sample of n items and locate their values on the ordinate scale. The observations need not be ordered beforehand as the plotting will order them naturally. Denote the smallest value by u_1, the second smallest value by u_2, ..., and the largest value by u_n. Locate the points (p_1,u_1), (p_2,u_2), . . . , (p_n,u_n) on the graphs and visually fit a straight line to these points. The values of p_1,p_2, . . ., p_n are found in Table I for $n \leq 20$. For all other n, let $p_i = \frac{2i-1}{2n}$.

If the same sample size is to be used over and over, the p_i can be plotted on the normal probability paper beforehand. The straight line can be used to estimate the percentage of observations falling outside the specification limits.

If there is only an upper specification limit, U, given, locate the value of U on the ordinate scale. It is important to have U (and/or L) appear on the graph. This may entail using an enlarged piece of normal probability paper in order to get a good line. The fraction of values falling below this limit is estimated by finding the abscissa where the fitted line intersects the line $u = U$. Call this value $1 - \hat{p}_U$. Determine $\hat{p}_U$ and accept the lot if $\hat{p}_U \leq p^*$. The value of p^* is found in Table II for a given AQL and sample size code letter.

TABLE I—Values of percentages (p_i) to be used in plotting on Normal Probability Paper for the "No Calc." procedure

n	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}
2	18.775									
3	14.020	50.000								
4	10.982	38.288								
5	8.940	31.271	50.000							
6	7.490	26.485	42.231							
7	6.416	22.979	36.620	50.000						
8	5.592	20.290	32.350	44.140						
9	4.942	18.159	28.979	39.537	50.000					
10	4.419	16.426	26.245	35.816	45.282					
11	3.988	14.990	23.980	32.740	41.392	50.000				
12	3.629	13.779	22.073	30.151	38.125	46.047				
13	3.326	12.746	20.444	27.941	35.339	42.682	50.000			
14	3.066	11.853	19.036	26.032	32.933	39.779	46.586			
15	2.841	11.075	17.807	24.365	30.834	37.248	43.631	50.000		
16	2.645	10.390	16.724	22.897	28.985	35.021	41.024	47.010		
17	2.473	9.783	15.764	21.595	27.345	33.045	38.712	44.361	50.000	
18	2.321	9.241	14.906	20.431	25.879	31.279	36.648	41.996	47.333	
19	2.185	8.7545	14.136	19.384	24.561	29.692	34.793	39.872	44.939	50.000
20	2.063	8.3158	13.439	18.438	23.370	28.258	33.110	37.962	42.779	47.589

Note: When $i > n/2$ use $p_i = 100 - p_{n-i+1}$

For $n > 20$ use $p_i = \frac{2i-1}{2n}$

TABLE II—Values of maximum estimated percentage defective allowing acceptance of the lot (p^*)

Code Letter	Sample Size	AQL								
		0.40	0.65	1.00	1.50	2.50	4.00	6.50	10.00	15.00
B	3					10.24	13.95	19.35	26.12	35.02
C	4			5.70	7.33	10.12	13.69	18.81	25.13	33.46
D	5		3.97	5.21	6.76	9.38	12.76	17.60	23.60	31.41
E	7	2.49	3.42	4.54	5.93	8.33	11.45	15.96	21.56	28.81
F	10	2.11	2.92	3.88	5.19	7.36	10.23	14.43	19.71	26.48
G	15	1.78	2.56	3.44	4.60	6.66	9.34	13.33	18.36	24.94
H	20	1.62	2.37	3.23	4.31	6.26	8.86	12.74	17.63	24.06
I	25	1.56	2.27	3.11	4.18	6.09	8.63	12.44	17.26	23.65
J	30	1.50	2.19	3.01	4.07	5.94	8.46	12.23	17.00	23.29
K	35	1.40	2.03	2.83	3.82	5.63	8.06	11.74	16.44	22.65
L	40	1.40	2.02	2.83	3.81	5.62	8.05	11.72	16.40	22.61
M	50	1.27	1.81	2.58	3.51	5.22	7.57	11.12	15.69	21.78
N	75	1.13	1.66	2.33	3.23	4.86	7.11	10.54	14.90	20.95
O	100	1.06	1.57	2.22	3.09	4.66	6.87	10.24	14.63	20.52
P	150	0.97	1.45	2.07	2.89	4.42	6.54	9.82	14.11	19.92
Q	200	0.96	1.43	2.05	2.87	4.38	6.49	9.76	14.04	19.84

*Work done under the sponsorship of the office of Naval Research under contract NSonr-25126.

‡Normal probability paper is available commercially, e.g., Keuffel & Esser Co., N. Y.

If only a lower specification limit, L, is given, locate the value of L on the ordinate scale. The fraction of values falling below this limit is estimated by finding the abscissa where the fitted line intersects the line $u = L$. Call this value $\hat{p}_L$. Accept the lot if $\hat{p}_L \leq p^*$. The value of p^* is found in Table II and is the same as that for the case of an upper specification limit.

For a double specification limit, both $\hat{p}_U$ and $\hat{p}_L$ are found in the manner described above. The lot is accepted if $\hat{p}_U + \hat{p}_L \leq p^*$. The value of p^* is also given in Table II.

The operating characteristic curves for the plans presented in Table II can be found in Reference (2).

It is important to caution the user, at this time, that the points (p_1,u_1), (p_2,u_2), . . ., (p_n,u_n) should appear to fall on a straight line. If this fails to happen, it may be an indication that the variable measured does not follow a normal distribution. In this case, existing variables techniques should not be used, and the lot should be accepted or rejected on the basis of attribute sampling.

Example: the specified minimum yield point for certain steel castings is 56500 psi. A 4 percent AQL plan is to be used with a sample size of ten. The yield points of the sample specimens are:

58380	57800
60440	62480
61520	60680
57180	59700
58880	59360

These points are plotted on the vertical axis as shown in Fig. 1. Thus $u_1 = 57180$, $u_2 = 57800$, ... , $u_n = 62480$. The values of p_i found in Table I for $n = 10$ are plotted on the horizontal axis. Thus $p_1 = 4.419$ percent, $p_2 = 16.422$ percent, ... , $p_n = 95.531$ percent. The points $(p_1,u_1) = (4.419$ percent, 57180); $p_2,u_2) = (16.426$ percent, 57800); . . . ; $(p_n,u_n) = (95.581$ percent, 62480) are located on the graph, and a straight line fitted to the data. Corresponding to $L = 56500$ psi, $\hat{p}_L$ is found to be 3.0 percent. From Table II, the value of p^* for a 4 percent AQL and a sample size of ten is 10.23 percent. Hence, the lot is accepted since $\hat{p}_L \leq p^*$.

Theory

It is well known that it is possible to transform the cumulative-normal-distribution curve to a straight line by means of a non-linear transformation of the horizontal scale. Graph paper possessing this property is known as normal probability paper. The abscissa scale represents a percentage, p, between 0 and 100, whereas the ordinate scale corresponds to the values of a normally distributed chance variable. The straight line, then, presents the percentage of values from a normal distribution falling below a specified value. For example, a normal distribution with mean ten and standard deviation three, plotted on normal probability paper, is shown in Fig. 2. The mean of the normal distribution can be determined by finding the ordinate where the line intersects $p = 0.5$, and the standard deviation can be determined by taking the distance between the ordinates where the line intersects $p = 0.8413$ and $p = 0.5$. The fraction of these values falling below some upper specification limit can be determined by finding the abscissa where the line intersects $u = U$. For example, in Fig. 2, 90 percent of the values fall below U.

If a sample of n independent observations is to be plotted on normal probability paper, it is natural to arrange them in ascending order, i.e., $u_1 \leq u_2 \leq \ldots \leq u_n$, and to plot a point corresponding to each observation.* Once the points $(p_1,u_1),(p_2u_2)$ . . . . . , (p_n,u_n) are plotted and a straight line is visually fitted to the points, the mean can be estimated as the ordinate where the line intersects $p = \frac{1}{2}$, and the standard deviation can be estimated as the distance between the ordinates where the line intersects $p = 0.8413$ and $p = 0.5$. The fraction of the values falling below U can be estimated by finding the abscissa where the line intersects $u = U$.

If the fraction defective is defined as the fraction falling above U (one minus the fraction falling below U), the above procedure leads to an estimate of the fraction defective. Denote this estimate by $\hat{p}_U$. The lot is rejected if $\hat{p}_U$ is too large. This statement can be made more precise if the lot is rejected when $\hat{p}_U > p^*$, where p^* is a fixed constant depending upon the O.C. curve chosen. The only problems remaining are to find an "optimal" estimate of $\hat{p}_U$ and to present a set of p^* corresponding to a given set of O.C. curves.

The estimate of the fraction defective depends upon the method of plotting and the plotting positions of the observed values. The authors have shown (1) that if the method of least squares is used, an optimal method of estimating the mean, standard deviation, and the value ξ such that the fraction of observations below ξ is a fixed constant, determines a fixed set of abscissas (p_i). These abscissas lead to optimal estimates in the sense of having minimum mean square deviations from the parameters estimated.‡ The values of p_i are presented in Table II for $n \leq 20$. Optimal values of p_i for $n > 20$ have not yet been computed. However, a glance at Table I reveals

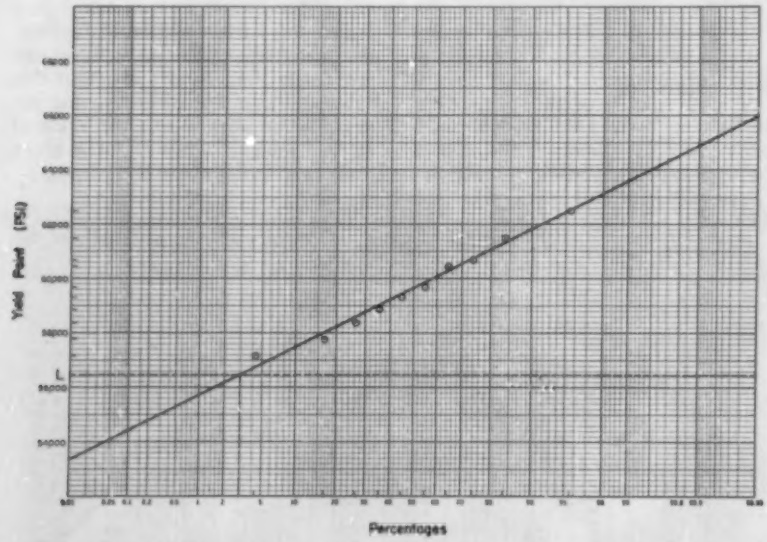

Figure 1—"No Calc" Procedure for Sampling Inspection by Variables, Plot of Percentage of Yield Points Falling Below a Specific Value

*The plotting positions of the p_i are somewhat arbitrary. This point is discussed when a set of values of p_i are presented.

‡In Reference (1) the authors have shown that the optimal estimates of the mean and standard deviation lead to a fixed set of abscissas. Subsequently, they have also verified that these abscissas will lead to a good estimate of ξ.

that an approximation is given by $p_i = \frac{2i-1}{2n}$. Furthermore, it has been shown[1,3] that this approximation leads to efficient estimates.

The distribution of the estimate, $\hat{p}_U$, is related to the distribution of the quantity $\frac{U-\bar{u}}{\hat{\sigma}}$ where $\bar{u}$ is the sample mean (obtained graphically by the method described previously), and $\hat{\sigma}$ is the estimate of the population standard deviation (also obtained graphically by the method described previously). The distribution of $\frac{U-\bar{u}}{s}$, where $(n-1)s^2$ is the sum of squares of the deviations of the sample values around the mean, is well known [2]. Operating characteristic curves for procedures based on $\frac{U-\bar{u}}{s} \geq k$, where k is a fixed constant, have been tabulated [2]. These curves are referenced according to AQL and sample size code letter.

The distribution of $\frac{U-\bar{u}}{s}$ and $\frac{U-\bar{u}}{\hat{\sigma}}$ are asymptotically equivalent, and hence, the asymptotic distribution of $\frac{U-\bar{u}}{\hat{\sigma}}$ is known. For n, a constant C is found such that the distributions of $\frac{U-\bar{u}}{s}$ and $\frac{U-\bar{u}}{C\hat{\sigma}}$ are approximately the same. This value of C has the property that the expected value of $C\hat{\sigma}$ is equal to the expected value of s, and the variance of $C\hat{\sigma}$ is approximately equal to the variance of s.* The values of p* presented in Table II are the probabilities corresponding to normal deviates of kC.

It has been indicated,[2] that the O.C. curve of the two-sided procedure depends almost entirely on the total percent defective (as opposed to the split between limits) when the optimal estimate of the percent defective[2] is used. Since the estimates presented in this article are good, the authors conjecture that the result holds for these estimates as well.

*The fact that the variance of $C\hat{\sigma}$ is approximately equal to the variance of s follows from the empirical results given in Reference (1).

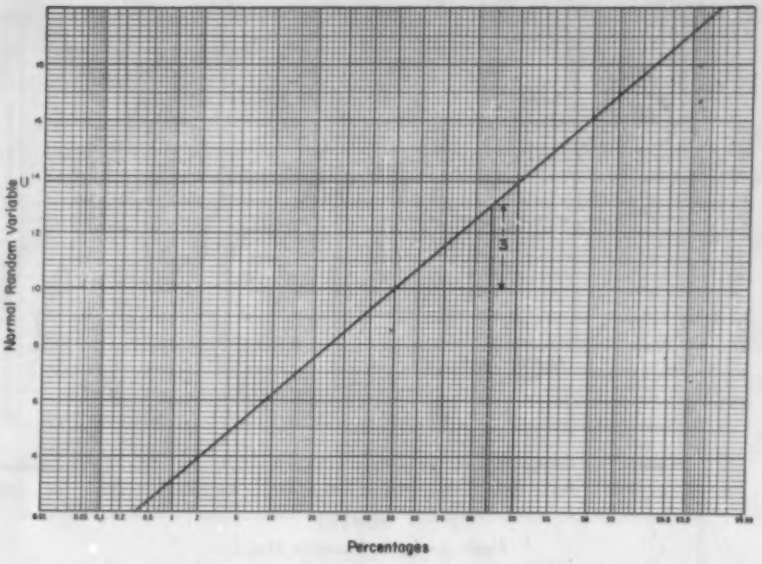

Figure 2—A Cumulative Normal Distribution with Mean 10 and Standard Deviation 3

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Statistical Inventory Control

W. F. HOEHING

Westinghouse Electric Corporation, Sharon, Pa.

Inventory Control Important to Sound Management

Every forward looking manager and owner wants his firm to achieve the status of a "growth company." Simply stated, a growth company is one where the dollar put up today earns the biggest return in the shortest time with respect to its competition at large. To achieve this enviable economic status, the company must obtain a maximum return-on-assets and its maximum share of the market. Other than such direct means as product design, price, sales effort, quality control, and cost reduction, inventory in most cases plays the most important role toward achieving these objectives.

The importance of inventory as a factor in this return-on-asset equation is readily accepted if the balance sheets of representative industrial companies are analyzed. From these analyses, it is common to find that inventories range from 10 percent to 40 percent of their gross assets. The questions the prudent manager must ask to assure himself that the large investment in inventories is earning its way among alternative capital investments are:

1. Is the inventory sufficient and deployed and controlled in a

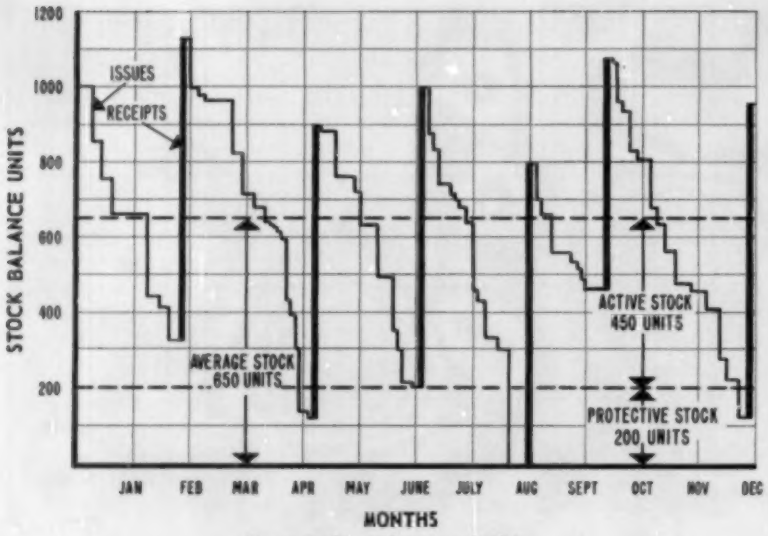

Figure 1—Stores Inventory Model

AUTHOR'S NOTE

The inventory control plan described in this article is applicable to situations of uncertainty of demand. When demand is known or fixed, for example through the development of monthly schedules or plans whereby the procurement, production, or distribution of the goods is set accordingly; or in the case where it is policy to minimize and control stock-outs through expediting effort, this plan does not apply per sé. Such planning and expediting actions preclude the free operation of chance occurances and introduces bias into the data. In Westinghouse we carefully segregate our stores inventory accounts into "planned" or "probability" accounts. The planned are the relatively few accounts having the high dollar volume of issues or sales. Requirements for these are developed and tied directly to specific sales and production forecasts or schedules, and thus represent known demand. The remaining low dollar volume items are the relatively large number of probability accounts which we control through the use of the techniques outlined here.

manner to achieve the maximum volume of sales?

2. Is the inventory too large, thus inflicting a restriction on the ability to earn a high rate of return?
3. Is the cost of operating the productive facilities and controlling the inventory low, thus contributing to maximum profit?

Here is the inventory paradox: Not too much, not too little, and at lowest cost for highest profit. The solution is the optimum inventory investment which can be achieved by making decisions based upon the costs involved. By recognizing the existence of the costs, the first step toward "management" control of inventories will have been taken.

In actual practice we know that the detailed control of inventory ultimately finds its way to the operating people or into a machine program. It is here that the inventory decisions are made for each and every item as to when and how much to buy or make. "How much of what, when" is the literal equation of inventory. If this equation is to be solved on a quantitative basis in accord with a management policy of maximum return on assets, then there must also be a method of communication so that the general decisions can be effectively and uniformly executed. This requires a system that has the means to absorb, and the mechanics to solve for, many variables of the demand (sales) and cost functions. Here is where mathematical and statistical methods can be used to extend management's quantitative decisions down-the-line and to keep the answers consistent with its cost and service objectives. With such a system, instead of the operator of, say, 1,000 stock items making an average of about 70 inventory decisions each day, trying to consider the effect of about 300 cost and demand values, he would work with management approved standards in the form of procedures into which are built the general decision rules.

The Function of Stores Inventory

In this article, we will show how we have used statistical methods to maximize the return-on-assets ratio. To cover the entire inventory picture would require discussions of work-in-process, miscellaneous and stores inventories. However, the techniques we shall deal with here apply only to the "stores" category. We define stores inventories as those raw materials, supplies, finished parts and finished goods which are procured and manufactured in larger quantities than required for the immediate future. The reasons for having stores inventories are:

1. To provide customer service; i.e., to have goods available in the time and quantity required to obtain sales and meet market objectives.
2. To obtain operating economy; i.e., to minimize such costs as procurement, machine setup and transportation.

To accomplish these objectives requires the answers to "when-to-order" and "how-much-to-order" each time. Before explaining the

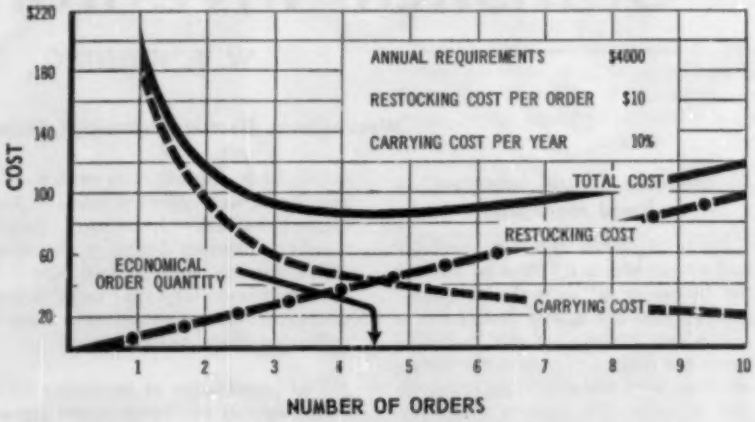

Figure 2—Economical Order Quantity

techniques which we use to answer the questions, it is necessary to study the characteristics of a stores inventory account. Figure 1 illustrates the behavior of a typical stores item.

Analyzing the graph we note that there are two distinct parts which we call the "active" stock and the "protective" stock. The protective stock is the average quantity on hand when restocking orders are received. The active stock is the difference between the average total stock and the protective stock. Knowledge of this permits us to effectively apply the service and economy control techniques.

We use the "economical ordering quantity" technique to control the active stock, essentially to achieve the economy objective. In a few words, this technique answers the question as to how much of a given volume of requirements (e.g., what amount of the expected annual sales or usage) should be procured and carried in inventory on the average such that the total of the carrying and restocking costs for the active portion of the stock are minimized. Figure 2 illustrates the economical ordering concept.

Here we note that the costs change with the frequency of the number of orders placed during the year. Actually the total cost is at a minimum where the carrying and ordering costs are equal, as is shown in the Appendix. This answers the question of "How much to order each time" and is also the point where the active portion of the inventory is at its optimum level.

When to Reorder Stock

The solution to the second question, "when-to-order," is far more complex and difficult than the answer to "how much." Briefly, stock must be ordered at a point in terms of quantity such that sufficient time is allowed for delivery before the stock is depleted. When to enter a restocking order is controlled by an order point based on the expected demand during the delivery time plus the amount of protective stock required to prevent no more than the desired number of stock-outs. Thus, the amount of protective stock, and consequently the degree of service, can be regulated by increasing or decreasing the order points as illustrated in Fig. 3.

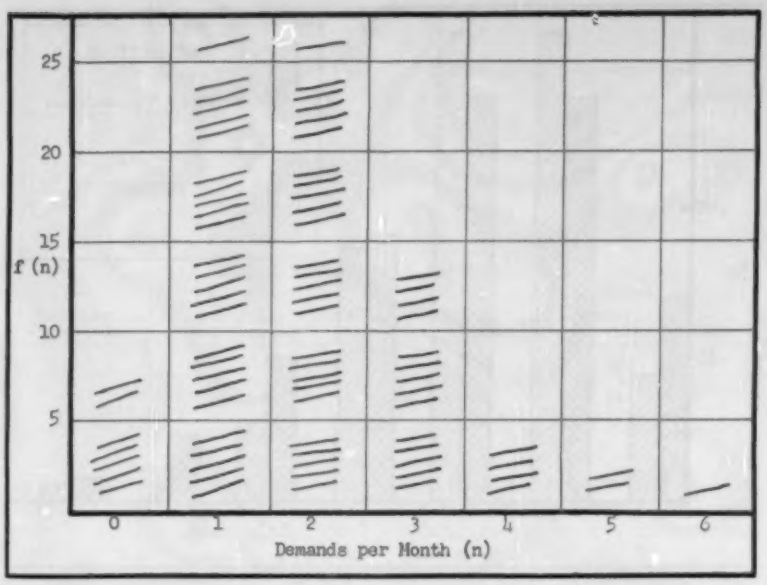

Figure 4—Distribution of Number of Demands Per Month for a Typical Stock Item

From this we can state two premises upon which we can establish the protective stock controls:

1. The only time we can get a stock-out is when a restocking order is open. This is because the order point (if set over zero) will force the placement of an order before the stock can be depleted. Hence, the protective stock problem can be narrowed down to what happens during the restocking time.
2. The frequency of the number of stock-outs is dependent upon the number of restocking orders issued. The number of orders is predicated upon an ordering policy; e.g., the aforementioned economical ordering procedure.

Hence to solve the "when-to-order" and service problems, we must control the inventory in such a manner to limit the number of stock-outs to, for example, one stock-out in a given number of chances. The most desirable condition would be to set order points so that the last unit of stock was used just as the restocking order was received. However, we know that accomplishing this is highly improbable in the long run because it is very likely, when left to chance, that deviations in issues will occur and cause stock-outs. Thus, if we are to set order points with which we can limit the number of stock-outs and consequently control the degree of service, the causes of stock-outs must be determined and allowances made for their occurrence. In reviewing the behavior of stores items, we found that there are three causes of stock-outs:

1. The number of demands (customer or shop orders) can be greater than expected.
2. The size of the demands (units per order) can be greater than expected.
3. The delivery or restocking time can be longer than expected.

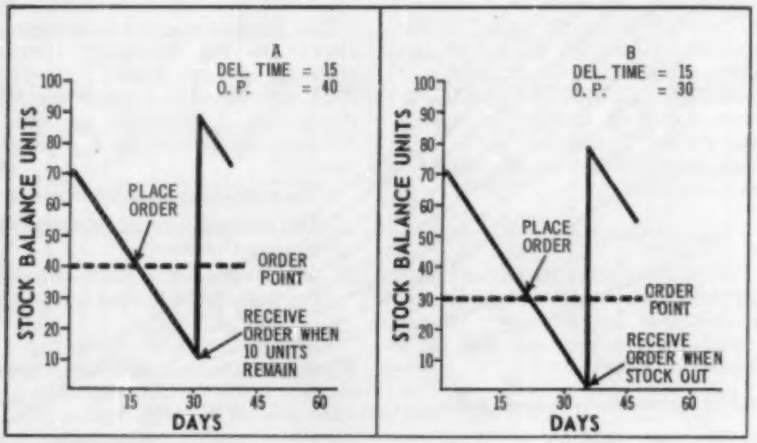

Figure 3—Effect of Order Point on Protective Stock, Stock-Outs, and Service

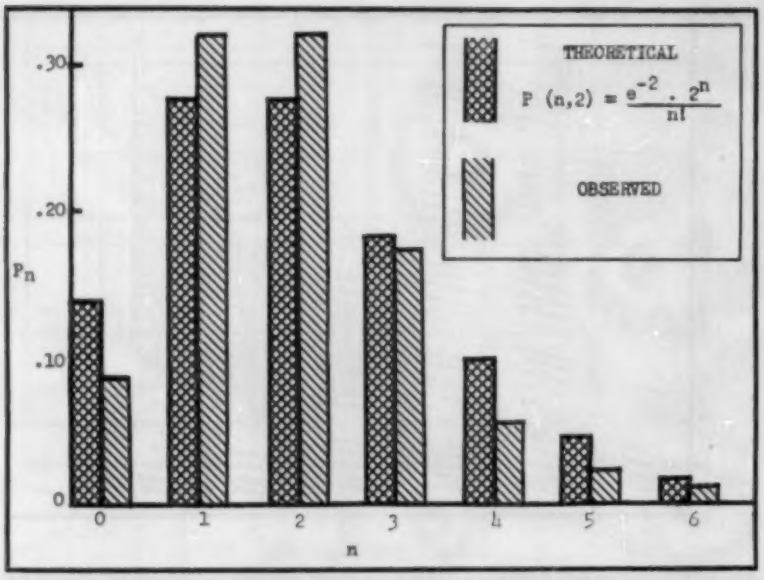

Figure 5—Relation of Observed Distribution to the Theoretical Poisson Distribution for m = 2

To allow for these occurrences and thus control inventories and service, we studied and learned something about their behavior. The problem was solved to our satisfaction by employing probability theory and statistical methods. In the remainder of the article, we will explain in detail the application of our method to one of the factors that can cause stock-outs, namely when the number of demands during the restocking time are greater than expected. After this we will explain the general operation of the procedures which introduce the other two factors, size of demand and delivery time.

Analyzing the Number-of-Demands Problem

In the demand problem, we worked with many stock items with the hope of discovering some consistency in their behavior that could be subjected to statistical analysis and control. We gathered data on the frequency of numbers of demands occurring during selected time intervals (per month in this case). The resulting distribution of the number of demands per month (n) for a typical stock item is shown in Fig. 4.

It will be observed that the distribution is skewed in a positive direction. After obtaining similar distributions for many other items, because of their appearance we chose to fit and test the data to a Poisson distribution. Figure 5 portrays the results.

Using the data from the example in Fig. 4, where actually 161 demands occurred during 80 months, we calculated the relative frequency of occurrence for each value of the number of demands per month (n) up to n = 6. The average number of demands per month (m) in this case was two. Next, to illustrate the fit, the Poisson distribution for m = 2 was calculated and constructed from the equation:

$$P(n,m) = \frac{e^{-m}\, m^n}{n!}$$

After many other studies and tests (χ^2 for the most part), we have concluded that the frequency of demands can be approximated by a Poisson distribution.

Solving the Number-of-Demands Problem

The next question is, "How can this knowledge be put to use in inventory control?" Our objective is to provide a given degree of service by placing restocking orders in time so as to control the frequency of stock-outs. Using the same case, we can plot the Poisson distribution for m = 2 as shown in Fig. 6.

Then using this distribution for illustrative purposes, we can calculate the chances of a given number of demands per month being exceeded. (In actual practice, tables similar to the condensed tabulation of Table I would be used.)

For example, as shown in the last column of Table I, we would expect that six demands would be exceeded 5 times in 1000 months; five demands, 17 in 1000; four demands, 53 in 1000; etc. Thus, referring back to Fig. 6, we can say that the occurrence of four demands per month will be exceeded 5 times in 100. This function can be stated in general terms in Table II, where each term represents the respective column in Table I.

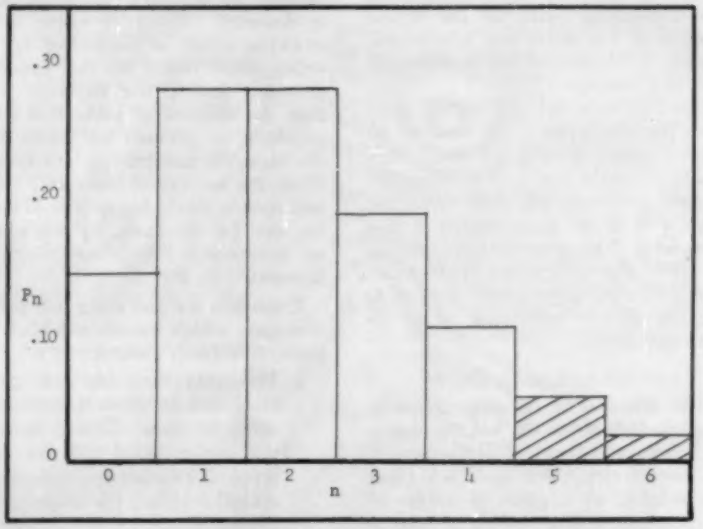

Figure 6—Poisson Distribution for m = 2

This procedure gives us a partial answer to the inventory control problem of how much protective stock is required to limit or control the chances of stock-outs occurring. For example, assume that for a stock item

- The restocking time is one month.
- The average number of demands per month is two.
- The chances of a stock-out occurring is to be limited to 5 times in 100.

This problem is set up in Fig. 6, where we note that the shaded area above n = 4 is about 5 percent of the total area of the distribution. This would indicate that although we expect only two demands during the

restocking interval, the time to enter a restocking order would be when the stock balance crossed the equivalent of four demands. Hence, we would require two demands' worth of protective stock to limit the probability of getting a stock-out to 0.05, or once in 20 chances.

Number-of-Demands Solution Extended to the General Case

The example discussed so far represents only a particular condition. To make a practicable application for inventory control, we must be able to handle a wide variety of conditions. Hence, in the general situations, we have two further considerations:

- Perhaps we should change the degree of protection from one stock-out in 20 chances to, say, one stock-out in 2, 3, . . . 10, etc. chances. This means that we must be able to calculate the values represented by an infinite number of areas under the curve.
- Also, it is known that the average number of demands during the restocking times will vary from one item to another.

To handle the first consideration above, selectivity of protection, we must agree upon a way to express the acceptable number of stock-outs; e.g., one stock-out per some number of chances which we expect to take during a finite period of time, say 1, 2, 3, etc., years. Earlier we established a basic premise which provides the key. It was that we can have stock-outs only when a restocking order is open. Consequently, the probability of going stock-out can be expressed as the ratio of the number of stock-outs desired to the number of orders placed (chances taken) per period of time (protective period).

For example, assume that the protective period chosen was five years and that only one stock-out (on the average) is desired for an item during that time; also, the number of restocking orders is expected to be at a rate of four per year. Then, 20 orders would be placed in the five year period, and only once do we want a stock-out. Therefore, the protective ratio can be stated as 1/20 or 0.05. By determining the frequency of ordering (which is variable and is calculated from the "economical" or other ordering practice) and establishing the protective period, any desired condition can be handled. This now gives us the ability to enter tables of the Poisson distribution (or approximate continuous curves similar to those shown in Fig. 7) with a specific protective criterion which, when solved, will give the proper order point in demands.

Before the system can be integrated, however, we must answer the second consideration above; i.e., that the average number of demands will vary item to item. This problem can be practicably solved by drawing a set of curves which represents the accumulative frequencies for the expected values of the Poisson distribution. Figure 7 is a set of curves for several values of m.

With the graph, the scheme now can be merged and we can find the order point for any desired degree of protection and for any particular expected number of demands. To use the graph calculate the desired protective ratio and enter the graph at the proper point on the "Protective Ratio" scale (top). Then proceed down vertically to the curve representing the expected number of demands, m, during the restocking or delivery time. The order point in demands can be read, opposite, on the left ordinate (n.)

TABLE I—Table of P (n,m) for m = 2

n	Frequency f	Cumulative Frequency F	Complementary Cumulative Frequency 1-F
0	0.135	0.135	0.865
1	0.271	0.406	0.594
2	0.271	0.677	0.323
3	0.180	0.857	0.143
4	0.090	0.947	0.053
5	0.036	0.983	0.017
6	0.012	0.995	0.005
7	0.003	0.998	0.002

TABLE II—Generalization of Table I

Demands Per Month	Probability of n Demands	Probability of n or Less Demands	Probability of Greater than n Demands
n	P(n,m)	$\sum_{x=0}^{n} P(x,m)$	$1 - \sum_{x=0}^{n} P(x,m)$

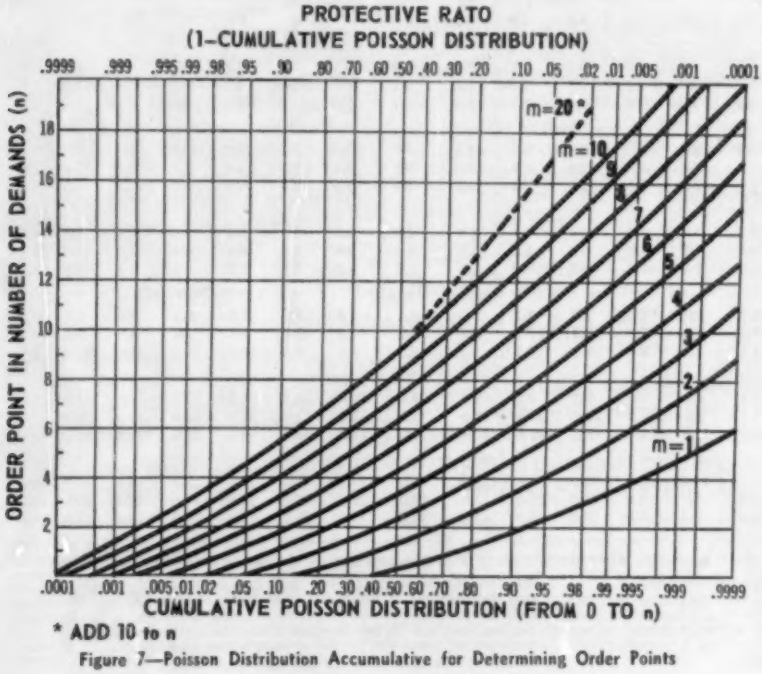

Figure 7—Poisson Distribution Accumulative for Determining Order Points

Size of Demands

Up to this point we have solved the first problem, that of protection against deviations in the size of demands. Realizing that the expected size of demands can be exceeded and also cause stock-outs, a certain amount of protection for that occurrence must be considered too. The size of demands is a negative exponential function with respect to the number of demands. That is, as the number of demands increases, the

number of units per demand will decrease, and the converse would be true as the number of demands decreases. In our experience, we have concluded that the exponential value of size of demands would vary depending upon the specific characteristics of the commodity, product, and business involved. Therefore, this factor should be calculated for each stocking location. It is our finding that this factor has relatively less weight than the number of demands. Once it is derived, it can be used in conjunction with the number of demands factor to obtain the total required protection.

Delivery Time

The final problem in determining "when" to place restocking orders concerns delivery time. Although in Westinghouse we consider protection against deviations in delivery times in certain instances, we prefer to use forecasts. Therefore, we have established the practice that the purchasing departments shall keep the material control groups advised of current supplier delivery times. By the same token, in the case of finished goods going to our customers, our own manufacturing divisions keep our regional sales groups advised of current shipping times.

The demand factors can be integrated into a set of tables for manual operation or programs for mechanical or electronic data processing. An order point table, which meets the particular needs of Westinghouse, is shown in Table III. Similar tables for various degrees of protection can be made using an extended set of curves similar to those in Fig. 7. However, since these tables would not compensate for the additional variability introduced by variation in the size of demands, some compensation must be made. The simplest approach would be to develop tables having a theoretical high degree of protection. By observing the actual stock-out experience, one could determine approximately how much the theoretical protection should be reduced to obtain the desired degree of actual protection.

To calculate order points using a manual system, all the operator needs to do is enter the table with the number of times per year stock is ordered (based on the economical order quantity) and the number of demands during the expected delivery time (from past records), and at the intersection read the order point in number of demands. Next, the order point must be converted into units. This is the product of the average size of demands (use same past records as for demands) and the order point in demands.

Giving Management the Needed Control

Thus far we have covered the technical aspects and operation of the stores inventory control scheme. It has been shown how quantitative and logical decisions can be made through the use of the economical order quantity and order point techniques. The economical order quantity is based upon the inventory costs involved and answers the question, "How much to make or buy?" The order point is based upon having sufficient protective inventory as determined by statistical methods to maintain a desired degree of service (or availability of inventory) and answers the other inventory question, "When to make or buy?" However, in operation these many down-the-line decisions are made day by day and item by item and lose their significance to the higher managements who are interested in whether or not the inventory is being controlled in a manner that achieves the established overall standards of performance. With this plan we have provided the manager with the means to raise or lower inventory levels and compensate for changes in operating cost (set up, interest, insurance, taxes, etc.) and to effect greater or lesser degrees of avail-

TABLE III—Order Point Table for 1 Stock-Out in 5 Years

ORDER REVIEW POINTS — SMALL NUMBER DEMANDS — PROTECTION: 1 STOCK OUT PER ACCOUNT IN 5 YEARS

AVERAGE NUMBER OF DEMANDS DURING DELIVERY TIME	NUMBER OF TIMES PER YEAR STOCK IS ORDERED																
	1.0	1.2	1.5	1.7	2.0	2.5	3.0	3.5	4.0	4.5	5	6	7	8	9	10	11	12
0.1	0.10	0.10	0.20	0.25	0.35	0.50	0.60	0.70	0.75	0.85	0.90	1.0	1.1	1.2	1.2	1.3	1.3	1.4
0.2	0.20	0.35	0.55	0.65	0.75	0.90	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
0.4	0.65	0.80	1.1	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.8	2.9
0.6	1.0	1.2	1.5	1.6	1.8	2.0	2.1	2.3	2.4	2.5	2.6	2.8	3.0	3.0	3.2	3.2	3.3	3.4
0.8	1.4	1.6	1.9	2.0	2.2	2.4	2.6	2.8	2.9	3.0	3.1	3.3	3.5	3.6	3.7	3.7	3.8	3.9
1.0	1.7	2.0	2.3	2.4	2.6	2.8	3.1	3.3	3.4	3.6	3.7	3.9	4.1	4.2	4.3	4.4	4.5	4.6
1.5	2.5	2.7	3.1	3.3	3.5	3.7	4.0	4.2	4.4	4.6	4.7	4.9	5.1	5.2	5.3	5.4	5.6	5.7
2.0	3.2	3.5	3.9	4.1	4.4	4.7	4.9	5.2	5.4	5.6	5.7	6.0	6.2	6.3	6.4	6.6	6.7	6.8
2.5	3.8	4.2	4.6	4.8	5.1	5.4	5.7	6.0	6.2	6.4	6.5	6.8	7.0	7.2	7.3	7.5	7.7	7.8
3.0	4.5	4.9	5.4	5.6	5.9	6.2	6.5	6.9	7.1	7.3	7.4	7.8	8.0	8.2	8.4	8.5	8.7	8.8
3.5	5.1	5.5	6.0	6.3	6.6	7.0	7.3	7.7	7.8	8.2	8.3	8.6	8.9	9.1	9.2	9.4	9.6	9.7
4.0	5.9	6.3	6.8	7.1	7.4	7.8	8.2	8.6	8.8	9.1	9.2	9.6	9.8	10.0	10.0	10.0	11.0	11.0
4.5	6.5	7.0	7.5	7.8	8.1	8.5	9.0	9.3	9.5	9.9	10.0	10.0	11.0	11.0	11.0	11.0	11.0	11.0
5.0	7.2	7.7	8.3	8.6	8.9	9.3	9.6	10.0	10.0	11.0	11.0	11.0	11.0	12.0	12.0	12.0	12.0	12.0
6.0	8.5	9.0	9.6	9.9	10.0	11.0	11.0	12.0	12.0	12.0	12.0	13.0	13.0	13.0	14.0	14.0	14.0	14.0
7.0	9.7	10.0	11.0	11.0	12.0	12.0	13.0	13.0	13.0	14.0	14.0	14.0	15.0	15.0	15.0	15.0	16.0	16.0
8.0	11.0	12.0	12.0	13.0	13.0	14.0	14.0	15.0	15.0	15.0	15.0	16.0	16.0	16.0	17.0	17.0	17.0	17.0
9.0	12.0	13.0	13.0	14.0	14.0	15.0	15.0	16.0	16.0	17.0	17.0	17.0	18.0	18.0	18.0	18.0	19.0	19.0

INSTRUCTIONS: Use this table for "probability" stock accounts, when deviations in number and size of demands must be considered.

1. Determine average number of demands during delivery time from ledger record.
2. Determine number of times per year stock is ordered from the Order Quantity Table.
3. At the intersection of the average number of demands and the number of times per year stock is ordered, find the Order Review Point in number of demands.
4. To express the Order Review Point in units multiply the number of demands by the average size of demands.
5. From 10 demands and up use standard tables.

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ability (which affects the number of delayed orders and lost sales). Along with this ability to change the level of inventory, we must have a means to control and interpret the decisions. For this purpose, after several years operation, a control curve of the type shown in Fig. 8 can be developed.

With such a control chart, management can make quantitative service and inventory decisions. Perhaps it is desired to increase the availability of stock several percentiles to accomplish greater sales volume or to reduce the cost of delayed orders (this would require operating with an order point table with a higher protection rate; e.g., one stock-out in three years instead of one stock-out in two years). The additional inventory required can be read in terms of supply rates from the control chart. To appraise the results of a given set of conditions attendant to a specific decision, the cost of carrying the additional inventory would be weighed against either the profit on the implied additional sales or the lower cost of delayed orders, as the case may be. Several sets of conditions should be considered before making a decision because one answer, although profitable, may not be optimal. The results of several sets of conditions should give the direction of the optimal profit.*

Essentially this is the Westinghouse scheme for controlling stores inventories and customer service. With it management can get inventory policy and quantitative decisions effectively executed, item by item, in a uniform manner. Further, when it is desired to make changes, these procedures provide a straightforward approach and make it possible to predict their effect in advance. With techniques such as these we can achieve "management control of inventories" and be assured that inventories are earning a maximum return on assets, the hallmark of a "growth company."

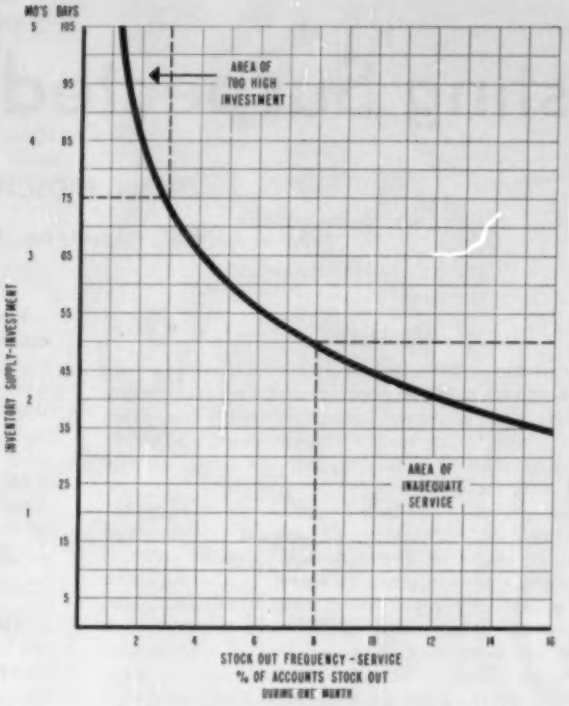

Figure 8—Inventory Supply and Service Control Chart

Appendix

Problem:

Find the economical order quantity in dollars for an item, considering restocking cost and carrying cost, given the following data:

1. Annual requirements (dollars per year)
2. Restocking cost* per order (dollars per order)
3. Carrying cost per year (dollars per dollar per year)

Solution:

(1) Total Annual Cost = Annual Restocking Cost + Annual Carrying Cost.

(2) If N is the number of orders per year, Q is the order quantity in dollars, R is the restocking cost per order, C is the annual carrying cost per dollar of inventory, and A is the annual requirements in dollars, then the total annual cost T is

$$T = NR + \frac{QC}{2}$$

$$= NR + \frac{AC}{2N}$$

(The above assumes that the average inventory is equal to one-half the order quantity.)

(3) Find the value of N for which the value of T is a minimum:

$$\frac{dT}{dN} = R - \frac{AC}{2N^2}$$

$$\frac{dT}{dN} = 0 \text{ when } R = \frac{AC}{2N^2}$$

$$\text{or } N = \sqrt{\frac{AC}{2R}}$$

(4) The economical order quantity is

$$Q = \frac{A}{N} = \sqrt{\frac{2AR}{C}}$$

Conclusion:

For the example shown in Fig. 2

$$N = \sqrt{\frac{AC}{2R}} = \sqrt{\frac{(4000)\,(0.10)}{(2)\,(10)}}$$

$$= 4.48 \text{ orders per year}$$

$$Q = \sqrt{\frac{2AR}{C}} = \sqrt{\frac{(2)\,(4000)\,(10)}{0.10}}$$

$$= 895 \text{ dollars per order}$$

Proof:

$$Q = \frac{A}{N} = \frac{4000}{4.48}$$

$$= 895 \text{ dollars per order}$$

Acknowledgement

The author wishes to recognize the valuable council and assistance by N. H. King and F. J. Carr during the preparation of this article, and the editorial suggestions by J. C. Emery.

* K. J. Arrow, T. Harris, and J. Marschak discuss the mathematical concepts and have established some rules for deriving the optimum inventory considering costs of (1) storage (carrying), (2) handling an order (restocking), and (3) depletion penalty (stock-out) in their paper "Optimal Inventory Policy", which appeared in *Econometrica*, Volume 19, No. 3, July, 1951.

*Note that this is not the "average" cost of placing an order but the "incremental" cost or the average change in total ordering costs as the number of orders placed is increased or decreased.

Testing Suspected Observations

FRANK PROSCHAN

Sylvania Electric Products Inc., Waltham, Mass.

Introduction

We are all accustomed in quality control work to take measurements on units of product, and then, depending on what we have observed, accept or reject the units. Now, what about taking measurements on units of product, and accepting or rejecting, not the unit, but the *observed measurement itself*?

Why would such a decision about an observed measurement itself be necessary? Clearly, if an observed measurement could be demonstrated to be in error, it would be quite advantageous to reject it. On the other hand, if a perfectly good observation were eliminated simply because it appeared suspiciously deviant from others on the same unit, bias and loss of information would result. Thus, it seems quite desirable to have some simple criterion for deciding objectively and with assurance whether a particular observed meaurement from a set should be eliminated or not.

This article makes available to the quality control engineer several of the simple, easy, modern statistical tests for possible rejection of outlying observations. Examples of their use in common quality control situations are presented.

Testing When No Estimate of Previous Variability Is Avaiiable

Consider the following common problem facing quality control engineers. Anna List, quality control chemist, makes a number (say three) of determinations of iron in aliquot parts of a sample of uranium. The smallest value (or the largest) is so far removed from the other two that she suspects that it may be in error. However, Anna has no specific knowledge that a mistake actually did occur. Let us assume that she has no previous data from which to estimate the precision of measurement. How can she decide *from the values themselves* whether the suspected value is in error or not?

The answer seems clear. She should consider the suspected value to be in error when it seems too far from the other two values. But how can she judge when it is "too far from the other two values"?

A Logical Approach

Here is a simple, logical, objective criterion. Suppose Anna could somehow make millions of sets of three observations each. Suppose, too, that she could guarantee that none of these observations had any mistakes. Call a typical set x_1, x_2, x_3, where the x's are arranged in order of size, so that $x_1 \leqq x_2 \leqq x_3$. Now a logical measure of the distance between the smallest value and the other two values is

$$r_{10} = \frac{x_2 - x_1}{x_3 - x_1},$$

i.e., the ratio of the interval between the suspected and adjacent value to the total range.

Now Anna records with what frequency, among her millions of sets of three values each, different values of r_{10} occur. She finds that a value of r_{10} larger than 0.941 occurs five times in one hundred. She then reasons this way:

"I have found that among sets of three observations each (containing no mistakes) a value of r_{10} larger than 0.941 is quite unlikely (occurs only five times in one hundred). If now, in my future experiments I get a set of three observations for which r_{10} is larger than 0.941, I will conclude that my smallest observation is in error."

Confidence in the Test

This seems reasonable. But what confidence can Anna have in such a procedure? How often will she consider as mistaken a perfectly good observation? How often will she consider acceptable an incorrect observation?

Clearly, from the way in which she derived the test, she will classify a perfectly good smallest observation as mistaken five times among one hundred sets of three each, on the average. But there is no general answer to the question of how often she will let pass a mistaken observation. This depends on *how* mistaken the mistaken observation is. If a very large error were made, her test would tend to reject the observation almost certainly. If a very small error were made, her test would tend to reject the observation with a small probability.

Figure 1 gives some idea of the performance of r_{10} in detecting mistaken observations. It is based on a sampling experiment in which samples of five (not three) from a normal population with a mean μ and standard deviation σ were contaminated with values drawn from a normal population with mean $(\mu + \lambda\sigma)$ and standard deviation σ. The ordinate shows the percent discovery of contaminators (the proportion of the time the contaminating population provides an extreme value and the test discovers this (value), while the abscissa shows λ, the magnitude of the shift (error) of the contaminator in standard deviations.)

We said above that once in every 20 sets of values (on the average) Anna would consider a perfectly good observation as mistaken. If she were to reject this observation and then compute the mean and standard deviation of the remaining values, these would be biased estimates. In addition, when a good observation is rejected, any further statistical tests of significance will become less reliable. This is the price that she must pay for "improving" the data in the cases where a good observation is mistakenly removed.

Mathematical Derivation

Of course, 0.941, the value of r_{10} that is exceeded by chance five percent of the time (called the five percent level of significance of r_{10}), is not determined by actually making millions of tests of three observations each. Rather it may be calculated mathematically (2) with even greater accuracy than if millions of sets of three

observations had been used. The basic assumption is that the repeated measurements would follow the normal distribution.

Larger Sample Sizes

For sample sizes larger than seven, slight modifications in the r_{10} statistic result in a more sensitive test. Thus for sample size $n = 8$, 9, or 10,

$$r_{11} = \frac{x_2 - x_1}{x_{n-1} - x_1}$$

is superior to r_{10}. Similarly for $n = 11$, 12, or 13,

$$r_{21} = \frac{x_3 - x_1}{x_{n-1} - x_1}$$

is superior. Finally for $n = 14, 15, \ldots, 25$,

$$r_{22} = \frac{x_3 - x_1}{x_{n-2} - x_1}$$

is best.

Use of Table I

Let us now define r as the appropriate statistic among r_{10}, r_{11}, r_{21}, and r_{22} according to the sample size. Table I gives critical values of r for significance levels $\alpha = 5$ percent and $\alpha = 1$ percent, for sample sizes from $n = 3$ to 25.

Thus, for example, for $n = 8$ and $\alpha = 5$ percent, the table gives a critical value for r (in this case r_{11}) of 0.554. This means that in 100 sets of eight observations each, free of mistakes, five values of r_{11} will be larger than 0.554, on the average.

What if Anna suspects the acceptability of the *largest* observation in a set? In this case, she simply uses the appropriately modified test ratio:

$$r_{10} = \frac{x_n - x_{n-1}}{x_n - x_1}, \text{ for } 3 \leqq n \leqq 7;$$

$$r_{11} = \frac{x_n - x_{n-1}}{x_n - x_2}, \text{ for } 8 \leqq n \leqq 10;$$

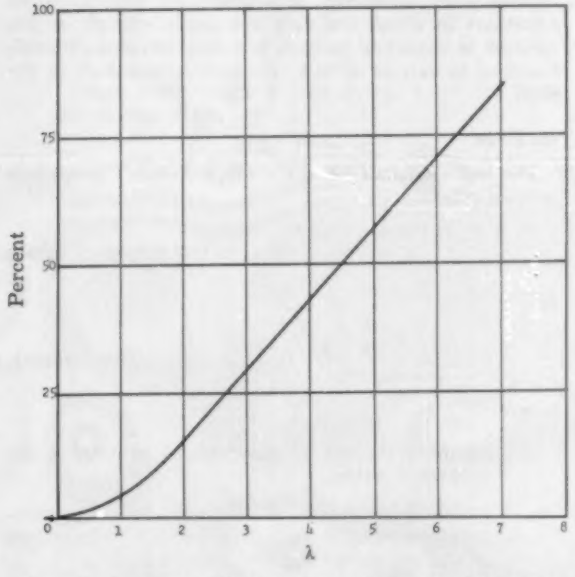

Figure 1—Performance of r test. The ordinate shows the percent discovery of contaminators, while the abscissa shows λ, the magnitude of the shift (error) of the contaminator in standard deviations. From W. J. Dixon, Ann. Math. Stat. 21, No. 4, 493 (1950).

TABLE I—Testing for Extreme Observation (No Past Data)*

N	Criterion	Significance Level‡ 0.10	0.05	0.01
3	$r_{10} = \frac{x_2 - x_1}{x_n - x_1}$ if smallest value is suspected:	0.886	0.941	0.988
4		0.679	0.765	0.889
5		0.557	0.642	0.780
6	$= \frac{x_n - x_{n-1}}{x_n - x_1}$ if largest value is suspected.	0.482	0.560	0.698
7		0.434	0.507	0.637
8	$r_{11} = \frac{x_2 - x_1}{x_{n-1} - x_1}$ if smallest value is suspected;	0.479	0.554	0.683
9		0.441	0.512	0.635
10	$= \frac{x_n - x_{n-1}}{x_n - x_2}$ if largest value is suspected.	0.409	0.477	0.597
11	$r_{21} = \frac{x_3 - x_1}{x_{n-1} - x_1}$ if smallest value is suspected;	0.517	0.576	0.679
12		0.490	0.546	0.642
13	$= \frac{x_n - x_{n-2}}{x_n - x_2}$ if largest value is suspected.	0.467	0.521	0.615
14	$r_{22} = \frac{x_3 - x_1}{x_{n-2} - x_1}$ if smallest value is suspected;	0.492	0.546	0.641
15		0.472	0.525	0.616
16		0.454	0.507	0.595
17		0.438	0.490	0.577
18	$= \frac{x_n - x_{n-2}}{x_n - x_3}$ if largest value is suspected.	0.424	0.475	0.561
19		0.412	0.462	0.547
20		0.401	0.450	0.535
21		0.391	0.440	0.524
22		0.382	0.430	0.514
23		0.374	0.421	0.505
24		0.367	0.413	0.497
25		0.360	0.406	0.489

*By permission, from W. J. Dixon, "Processing Data for Outliners," *Biometrics*, March 1953, Vol. 9, No. 1, Appendix, Page 89.
‡Risk of rejecting a perfectly good extreme observation.

$$r_{21} = \frac{x_n - x_{n-2}}{x_n - x_2}, \text{ for } 11 \leqq n \leqq 13; \text{ and}$$

$$r_{22} = \frac{x_n - x_{n-2}}{x_n - x_3}, \text{ for } 14 \leqq n \leqq 25.$$

Why are several significance levels given? The reason is that no one significance level is appropriate to all situations. In general, if, based on previous experience, relatively many large errors are expected to occur, a large risk of rejecting a perfectly good extreme observation should be used. At the other extreme, if previous experience has shown that errors are quite unlikely and are generally small when they do occur, then a smaller risk of rejecting a good observation should be used. This follows from the fact that the loss in accuracy of the sample of, say, the population mean as a result of wrongly removing perfectly good values is more than overbalanced by the corresponding loss in accuracy as a result of retaining grossly mistaken observations. Exact rules are given in Reference (1) for the proper choice of the significance level, in terms of the expected size and frequency of errors.

Since, unfortunately, in quality control work, the expected size and frequency of error is generally not known, it is (somewhat arbitrarily) recommended that the five percent level of significance be used for the r-test. If, however, based on past experience, very few and relatively small errors are expected in a particular application, then the one percent level of significance should be used. On the other hand, if experience shows that errors occur often or are large in a particular situa-

tion, then the ten percent level of significance should be used.

Examples

(a) Anna List, quality control chemist, obtains the values

43 41 62

for replicate determinations of the iron content in three aliquot parts drawn from the same sample of uranium. She suspects that the third observation is in error, since it is so much larger than the other two. However, she has never before run determinations of iron in uranium using her present equipment; hence she cannot use past experience to estimate the usual measurement error. How can she tell from the present set of three measurements whether to reject or retain the value 62?

Since no previous data are available from which to compute the precision of measurement, the r-test is appropriate. Her first step is to arrange the three values in order of size:

$$x_1 = 41 \qquad x_2 = 43 \qquad x_3 = 62$$

Then she computes

$$r = r_{10} = \frac{x_3 - x_2}{x_3 - x_1} = \frac{62 - 43}{62 - 41} = 0.905.$$

Note that she takes the difference between the largest value in the set and its neighboring value for the numerator of r_{10}; this is because the suspected value is the largest in the set, rather than the smallest. Finally, since the computed value of r_{10}, 0.905, is *smaller* than the corresponding table value of r_{10} at the five percent level of significance, 0.941, Anna List concludes that she will retain the suspected observation 62.

(b) Norris G. Neer, quality control engineer, is required to measure the density of a slurry in a large process tank. After the contents of the tank have been mixed for what he considers a reasonable length of time, N. G. Neer obtains four samples of the tank's contents, and observes values of:

3.17 3.21 3.11 3.50

Since the value 3.50 was obtained for the sample representing the bottom quarter of the tank, N. G. Neer suspects that the slurry was not mixed well enough, the denser material remaining on the bottom. From the observed values above, how can he decide quickly, but with assurance, whether the value 3.50 is sufficiently far removed from the other values to justify the expense of another set of samples from the tank? Since the slurry varies considerably in content from time to time, past data as to normal sample variability are not applicable. However, N. G. Neer knows from experience that rejectable extreme values as a result of inadequate mixing of the slurry have occurred fairly often in the past.

N. G. Neer first arranges the observations in order of size:

x_1	x_2	x_3	x_4
3.11	3.17	3.21	3.50

Next, since the sample size is four, and since the suspected value is the largest in the set, he calculates

$$r_{10} = \frac{x_4 - x_3}{x_4 - x_1} = \frac{3.50 - 3.21}{3.50 - 3.11} = \frac{0.29}{0.39} = 0.744$$

He decides to use the ten percent level of significance because of the previous high frequency of sampling error. Since the calculated value, 0.744, is larger than the corresponding table value at the ten percent level of significance, 0.679, N. G. Neer concludes that the suspected value 3.50 is sufficiently far removed from the other three values in the set of observations to warrant the conclusion that it is from a different population, i.e., the contents of the tank were not well mixed. N. G. Neer is thus sufficiently bolstered to call for a new sampling of the tank.

(c) Beatrice Ginner realizes that for the first of three aliquots she has spilled a few drops of solution in the process of obtaining a chemical analysis of impurity content. The results turn out to be:

Aliquot Number	1	2	3
Measured Impurity Content	0.12	0.10	0.09

Should Bea Ginner use the r-test to determine whether the aliquot No. 1 result should be dropped?

No!

Since she actually *observed* the mistake occurring, she should eliminate the result as being in error, and either take an additional measurement or use only the remaining observations. The statistical tests described in this article apply only if no actual mistake was observed during the course of measurement.

Testing When Estimate of Previous Variability Is Available

In a great many quality control situations, past data *are* available for estimating the uncertainty of a measurement. It is clear that where such information is available, it should be used in deciding whether an outlier is mistaken or not. This will make the decision more reliable than if only the one set containing the suspected value is used.

Two procedures will be described for testing outlying observations, where past data are available as to measurement variability. The first is statistically more efficient, but requires more tedious calculations. It probably would not be commonly used in routine quality control work. However, it is presented here to cover situations in which the data are costly enough or the decision is important enough to justify the extra trouble required to extract all the information contained in the data.

The u-Test

The more efficient (in the statistical sense) procedure is to calculate

$$u = \frac{x_n - \bar{x}}{s_d} \text{ (if } x_n \text{ is the suspected value)}$$

or

$$u = \frac{\bar{x} - x_1}{s_d} \text{ (if } x_1 \text{ is the suspected value),}$$

where

$\bar{x}$ = mean of the set of observations containing the suspected value

s_d = standard deviation of an individual measurement, based on d degrees of freedom independent of the set containing the suspected value.

Next compare the computed value of u with the corresponding value in Table III, using the five percent level of significance in general. If the computed value

TABLE II—Data Available Previously

Specimen	Aliquot			Specimen	Aliquot		
	1	2	3		1	2	3
1	41	37	40	5	46	50	40
2	57	55	59	6	53	60	54
3	50	53	46	7	37	31	36
4	61	65	75	8	46	41	48

is as large as the tabulated value for the appropriate number of degrees of freedom, conclude that the suspected value is rejectable; otherwise retain the suspected value.

As for the choice of significance level, the same considerations apply here as before: use the five percent level of significance, unless experience has shown that size and frequency of mistakes are relatively large or relatively quite small. If experience has shown that the errors are relatively large or frequent, use the ten percent level of significance. If experience has shown that errors are relatively infrequent or quite small, use the one percent level of significance.

Example

In example (a) previously, Anna List was forced to use the r test since she had no previous experience as to the uncertainty of measurement of iron in uranium using her present equipment. Suppose now, she had been performing the same type of measurement over a period of time, and had available as to measurement variability the data contained in Table II.

Since previous experience is available for estimating measurement uncertainty, the u-test would be superior to the r-test. First, Anna List calculates s_{16}, the standard deviation of the data of Table II containing 16 degrees of freedom (eight sets containing two degrees of freedom each). The standard deviation, s_{16}, for the pooled data of Table II would be calculated from

$$s^2_{16} = \frac{1}{16}\Big\{[41^2 + 37^2 + 40^2 - (41 + 37 + 40)^2/3] + \ldots [46^2 + 41^2 + 48^2 - (46 + 41 + 48)^2/3]\Big\} = \frac{271.33}{16} = 16.96$$

Hence $s_{16} = 4.1$

Next Anna computes the mean, $\bar{x}$, of the three observations of the set

$$\bar{x} = \frac{43 + 41 + 62}{3} = \frac{146}{3} = 48.7$$

Now she is ready to apply the u-test. To do so, she substitutes into

$$u = \frac{x_3 - \bar{x}}{s_{16}}$$

obtaining

$$u = \frac{62 - 48.7}{4.1} = 3.24$$

Next, Anna compares the calculated value of u, 3.24, with the corresponding Table III value at the five percent level of significance, 1.90; since the calculated value is the larger, Anna concludes that the suspected value, 62, is probably in error and rejects it.

Note that the r-test applied earlier led to *retention* of the suspected value, while the present u-test leads to its rejection. The reason for the difference is the fact that the additional past data of Table II demonstrated that the variability of measurement was relatively small, and that measured against this relatively small variability, the observed deviation of the suspected value was significantly large. Thus, when past experience as to measurement variability is available, the u-test is superior to the r-test, and as observed in the present illustration, may lead to a different answer.

Control Chart for Ranges

From the illustration of the preceeding section, it may have become apparent that because of the rather tedious calculations required for the u-test, it is not especially well suited for quality control applications. An alternative procedure is now described which is much more convenient, rapid, and suited to the quality control approach.

Suppose the situation is one in which routine replicate measurements are made regularly. For example, in the illustration in which Anna List measured the iron content in uranium, suppose triplicate measurements were made on a new sample each hour. A simple and effective procedure for statistically controlling the occurrence of gross errors is to maintain a control chart for *ranges*. The range of the set of replicate measurements reflects the ordinary measurement variability; when a mistake occurs resulting in a sufficiently extreme value, the range for that set becomes unusually large and falls outside of control limits. Note that although the sets of replicate measurements are for different samples of uranium, the *ranges* are nevertheless comparable, since the amount of measurement variability is assumed relatively constant with time.

TABLE III—Upper percentage points of the "Studentized" extreme deviate, $u = (x_n - x)/s_\nu$ or $u = (x - x_1)/s_\nu$.*

d \ n	10% points							5% points							1% points						
	3	4	5	6	7	8	9	3	4	5	6	7	8	9	3	4	5	6	7	7	9
10	1.68	1.93	2.11	2.25	2.36	2.46	2.54	2.02	2.29	2.49	2.63	2.75	2.85	2.93	2.76	3.05	3.25	3.39	3.50	3.59	3.67
11	1.66	1.91	2.08	2.21	2.32	2.42	2.49	1.99	2.26	2.44	2.58	2.70	2.79	2.87	2.71	3.00	3.19	3.33	3.44	3.53	3.61
12	1.65	1.89	2.05	2.19	2.29	2.38	2.46	1.97	2.22	2.40	2.54	2.65	2.75	2.83	2.67	2.95	3.14	3.28	3.39	3.48	3.55
13	1.63	1.87	2.04	2.16	2.27	2.36	2.43	1.95	2.20	2.38	2.51	2.62	2.71	2.79	2.63	2.91	3.10	3.24	3.34	3.43	3.51
14	1.62	1.85	2.02	2.14	2.25	2.33	2.41	1.93	2.18	2.35	2.48	2.59	2.68	2.76	2.60	2.87	3.06	3.20	3.30	3.39	3.47
15	1.61	1.84	2.00	2.13	2.23	2.31	2.39	1.92	2.16	2.33	2.46	2.56	2.65	2.73	2.57	2.84	3.02	3.16	3.27	3.35	3.43
16	1.61	1.83	1.99	2.12	2.22	2.30	2.37	1.90	2.14	2.31	2.44	2.54	2.63	2.70	2.55	2.81	3.00	3.13	3.24	3.32	3.39
17	1.60	1.82	1.98	2.10	2.20	2.28	2.35	1.89	2.13	2.30	2.42	2.52	2.61	2.68	2.52	2.79	2.97	3.10	3.21	3.29	3.36
18	1.59	1.82	1.97	2.09	2.19	2.27	2.34	1.88	2.12	2.28	2.41	2.51	2.59	2.66	2.50	2.77	2.95	3.08	3.18	3.27	3.34
19	1.59	1.81	1.97	2.09	2.18	2.26	2.33	1.87	2.11	2.27	2.39	2.49	2.58	2.65	2.49	2.75	2.92	3.06	3.16	3.24	3.31
20	1.58	1.80	1.96	2.08	2.17	2.25	2.32	1.87	2.10	2.26	2.38	2.48	2.56	2.63	2.47	2.73	2.91	3.04	3.14	3.22	3.29
24	1.57	1.78	1.94	2.05	2.15	2.22	2.29	1.84	2.07	2.23	2.35	2.44	2.52	2.59	2.43	2.68	2.85	2.97	3.07	3.15	3.22
30	1.55	1.77	1.92	2.03	2.12	2.20	2.26	1.82	2.04	2.20	2.31	2.40	2.48	2.55	2.38	2.62	2.79	2.91	3.01	3.08	3.15
40	1.54	1.76	1.89	2.01	2.09	2.17	2.23	1.80	2.02	2.17	2.28	2.37	2.44	2.51	2.34	2.57	2.73	2.85	2.94	3.02	3.08
60	1.52	1.73	1.87	1.98	2.07	2.14	2.20	1.78	1.99	2.14	2.25	2.33	2.41	2.47	2.30	2.52	2.68	2.79	2.88	2.95	3.01
120	1.51	1.71	1.85	1.96	2.05	2.12	2.18	1.76	1.97	2.11	2.21	2.30	2.37	2.43	2.25	2.48	2.62	2.73	2.82	2.89	2.96
∞	1.50	1.70	1.83	1.94	2.02	2.09	2.15	1.74	1.94	2.08	2.18	2.27	2.33	2.39	2.22	2.43	2.57	2.68	2.76	2.83	2.88

*By permission, from K. R. Nair, "Tables of percentage points of the 'Studentized' extreme deviate from the sample mean," *Biometrika*, April 1952, Vol. 39, Parts 1 and 2, p. 190 and 191.

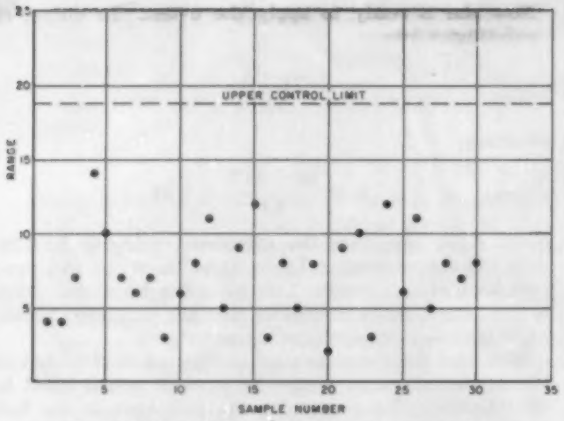

Figure 2—Control Chart for Ranges: Iron in Uranium

Clearly, as in the standard control chart procedure, the number of observations per range must remain fixed, and should not exceed 12[4, p. 294]. In general, the standard rules for constructing and maintaining control charts for ranges[4] apply to the present application of testing for deviant values.

Example

Suppose Anna List is required to make routine determinations in triplicate of iron in uranium samples twice a day. She wishes to maintain a simple, convenient control system which will automatically "ring a bell" when any observation is excessively deviant from the others in the set. How shall she go about it?

Anna List simply sets up a control chart for ranges. Suppose the observations for the past 30 samples are as shown in Table IV.

As usual in constructing a control chart for ranges, the average range, $\overline{R} = 7.27$, is multiplied by factors $D_3 = 0$ and $D_4 = 2.575$ (for sample size three) to yield lower and upper control limits of 0 and 18.7 respectively.

Anna List is now ready to apply her controls. She constructs the range chart shown in Fig. 2.

Suppose now her next (thirty-first) sample yields the triplicate observations listed originally in Example (a):

43 41 62, with $R_{31} = 21$

Clearly the present sample range, 21, lies *above* the upper control limit; hence Anna List may reasonably conclude that the dispersion among the triplicate values of sample no. 31 is excessive and reflects a mistake of some kind. With clear conscience, Anna eliminates 62 and uses only the two remaining observations 43 and 41. (Or else, she may analyze one or more aliquots for sample no. 31).

Cautions and Comments

(a) Obviously, if the experimenter *knows* by direct observation that a mistake has occurred he should reject the observation. The tests of this article are used only if he does not know that a mistake has occurred.

(b) If the experimenter uses this technique for a certain routine type of measurement, he should apply it, implicitly or explicitly, every time he makes that type of measurement. After several explicit applications of this technique, he will probably be able to perform the r (or u) test in all but the most doubtful cases without actually explicitly doing the arithmetic, since he will have the critical value of r (or u) in mind. He should not, however, reject outliers by the r test in some cases and accept others just as badly deviating, simply because he did not apply the test in these latter cases.

(c) Both the r and u tests are based on the assumption that repeated measurements of the same unknown follow the *normal frequency distribution*. If, in actual practice, the distribution of repeated measurements is markedly different from the normal curve, then the use of these tests will lead to different risks than originally intended.

(d) Suppose the type of measurement is such that the suspected value will practically always be the smallest in the set, or practically always the largest. Then using the five percent level of significance, five percent of the time a perfectly good observation will be rejected. Suppose, however, the type of measurement is such that the suspected value may be *either* the largest or the smallest. In this case about ten percent of the time a perfectly good observation will be rejected when we use the five percent critical value.

(e) The procedures of this article may be used for testing a set of replicate measurements of the *same* unknown quantity for a possible mistake in measurements, or for testing a set of observations on *different* units (of product, say) to determine if one of the units is from a population different from that of the others. Thus, Example (a) of the r-test illustrates the case of repeated measurements of the same unknown quantity, in which the outlying observation (62) is tested to determine whether it is the result of a gross error or not. On the other hand, if the three observed values of iron in uranium, 43, 41, and 62 had been obtained for *successive* batches of product, the very same r-test could have been used to determine whether the batch yielding the high value, 62, was from a different population than that which gave rise to the other two values 43 and 41. It is assumed, of course, in using the r-test, that no previous data are available, in either case, to furnish an estimate of variability.

(f) Other tests for rejection of suspected values are available[3]. However, the r and u test ratios and the control chart for ranges have been selected as being among the more convenient and practical tests.

(g) Note that using the control chart for ranges, a lower control limit is also calculated. If a sample range were to fall *below* the lower limit, it would imply that the agreement among the observed values in a set was *unusually* good. In certain quality control situations,

TABLE IV—Iron in Uranium Samples

	Sample Number																													
Iron Aliquot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Av.
1	41	57	50	61	46	53	37	46	51	55	49	48	41	51	42	41	62	60	56	48	51	39	46	51	45	49	41	49	42	61	
2	37	55	53	65	50	60	31	41	48	50	41	52	46	56	39	41	54	62	52	47	42	43	46	39	49	38	46	41	43	69	
3	40	59	48	75	40	54	36	48	48	49	44	59	44	60	30	44	59	57	48	49	50	49	49	50	51	42	43	48	49	64	
Sample Range	4	4	7	14	10	7	6	7	3	6	8	11	5	9	12	3	8	5	8	2	9	10	3	12	6	11	5	8	7	8	7.27

this would lead to the conclusion that doctoring of data had occurred. Hence, in such situations, the lower control limit of the control chart for ranges may turn out to be as useful as the upper control limit.

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SUPERVISOR'S CIRCLE

PAUL A. ROBERT, *Editor*

Gruen Watch Company, Time Hill, Cincinnati 6, Ohio

Product Standards and Specifications in the Gage Control Program

LEONARD F. MYERS, *Eastman Kodak Co., Rochester, N. Y.*

The basic function of a Gage Control organization is that of a service department, and in most instances they do operate as service groups. Such an organization performs several duties essential in any Quality Control program. Generally speaking the services rendered, among others, consist of establishing dimensional and other specifications for gages and measuring instruments, and of seeing to it that the items actually conform to their specifications. Thoughtful evaluation of this common understanding of the gage control activity will reveal that we are not giving as much service as can and should be provided. By operating with activities restricted to those mentioned, we are ignoring the ambiguities of the terms used. These terms precisely used and understood are the whole foundation for doing anything predictably. In short, a gage control department, before it can correctly and properly do anything about gage specifications, must first determine what is meant by the dimensional product specifications it has received. It is vitally important to recognize that these specifications must be precise, and must be expressed in such form and language that the engineering information involved will have exactly the same, precise meaning to each and every individual who may have occasion to deal with it. The following discussion is intended to point up, in a general way, the importance of a few of these factors.

For some reason, it is easy to teach most people to use instruments precisely (a synonym, in this case, for predictably). But it is difficult, in fact almost impossible, to make those same people understand that a given term—"Class X," or "¼—20 UNC—2A," or "tolerance," etc.—must always be used with the same meaning, if the person reading it is to react predictably.

Comments of the Editor

The thoughts expressed by the author are deep in the conscience of all Chief Inspectors.

How many of us have taken the time and given the thought necessary to formalize some of these "hairy" areas?

1. *Do you know what percentage of the part tolerance is taken up by gages? by production tooling?*
2. *Do you know when gages have worn beyond acceptable limits?*
3. *How much out of tolerance can a dimension be before your inspectors call the part defective?*

What do you think should be done to reduce inspection to a more exact science?

The need for carefully expressed information becomes apparent to anyone as soon as he begins to try to specify gages to a series of drawings that are not uniform.

These facts seem so simple as to be obvious, but let us consider some examples.

Any modern table of decimal equivalents tells you that $\frac{3}{32}$ inches and 0.0938 are equivalent, but if one drawing specifies a hole of 0.0938 diameter and another of $\frac{3}{32}$ inches diameter a gage designer must decide whether two different gages are necessary. That question should already have been answered by the person who made the drawing. The expression of a thread required may be shown as ¼—20. The determination of whether UNC—2A or NC—2 is required must be made by someone. Here again proper and complete specifications by the draftsman would save time and confusion.

These examples should be enough to show that drawings must be uniform in order to enable the gage people to do their job precisely and economically. Gaging is too precise a science to be founded on guesswork and assumptions, approximations are not good enough.

The skill of a designer in recording his wishes with such clarity and correctness that no ambiguity exists or misinterpretation can be made, is no less important than his ability

(Continued on page 22)

ASQC CONVENTION EXPOSITION CHART

AMERICAN SOCIETY FOR QUALITY CONTROL

11th Annual Convention • Masonic Temple • Detroit, Mich. • May 22-24, 1957

RED-LETTER DATES FOR THE NATION'S FASTEST GROWING PROFESSION.

Are you suffering from a slight—or serious—case of the January doldrums and looking forward longingly to those pages of your new calendar that carry pictures of Spring in full bloom? Then why not take a minute right now to turn to May and put a big red circle around the 22nd, 23rd and 24th—the dates of our 11th annual convention-exposition. Now is the time to make plans to attend what will be our most stimulating and informative convention. ASQC members in and near the "Motor City" will be our hosts in the Masonic Temple building which can comfortably house all meetings, exhibits and daily luncheons under one roof. The excellent program of speakers and subjects will be announced on this page as soon as possible. As we all know, quality control is growing enormously in scope and importance. To keep informed of the direction this fast moving profession is taking, you'll want to be in Detroit in May.

Fascinating, informative exhibits by the industrial leaders serving this fast growing field will include the following names.

American Cystoscope Makers, Inc.
Basic Service Corp.
Bausch & Lomb Optical Co.
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Continental Can Co.
Convair
M. E. Cunningham Co.
The DoAll Co.
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Service Diamond Tool Co.
The Sheffield Corp.
The L. S. Starrett Co.
Sunnen Products Co.
The Taft-Peirce Mfg. Co.
Triplett & Barton, Inc.
Unit Process Assemblies, Inc.
Wilson Mechanical Instrument Div. of American Chain & Cable Co. Inc.

"THE STORY OF MEASUREMENT".

Representatives of The DoAll Company announce that they will present their dramatic new exhibit "The Story of Measurement" at the 11th annual convention-exposition. This will be in addition to their product exhibit. As noted in the October issue of INDUSTRIAL QUALITY CONTROL, "The Story of Measurement" is told by means of cinerama-type slides with accompanying commentary and a display of measuring instruments from ancient times down to the present day. The application of precision measurement to today's production methods is a feature of special interest to quality control engineers.

LOOK FOR THESE FEATURES AT THE EXPOSITION

A special attraction of the L. S. Starrett Company exhibit will be their entirely new satin chrome plated vernier caliper with open face vernier. You can also see a complete display of their precision hand measuring tools, including their new line of dial indicators and dial gages.

Karl Heitz Inc. will demonstrate the marvelous accuracy of the Swiss ALPA 35mm camera, especially for close-up and microscopic photography. The company points out that this flexible instrument is a precision recording tool in the hands of the scientist and research engineer.

Unit Process Assemblies, Inc. will display their new Dermitron Non-Destructive Thickness Tester for the measurement of coatings of metals on metals, non-conductors on metals and metals on non-conductors. Several Dermitron instruments will be in continuous operation, measuring various coatings.

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January 16, 1956

ASQC Members and All Disciples of the Laws of Probability:

Ten conventions have established a precedent and a pattern. An A.S.Q.C. Convention leaves nothing to probability—it is a carefully planned annual event which is enthusiastically received.

How fitting that Detroit, the Dynamic, should start the second decade! Here, in the automobile capital of the world, close tolerance, precision, and adherence to tight specifications are all part of the daily routine and all are applied to thousands—even millions—of units. Here the newest scientific developments are welcomed.

Detroit as a convention city offers much to the visitors. Beautiful Belle Isle, the new civic center, Greenfield Village, and neighboring Canada are just a few of the many attractions. Here one can find beauty and culture in harmony with industry and commerce.

Your local committee has been working diligently for months to make the coming convention an outstanding affair. There will be eighty technical sessions—more numerous and more varied exhibits than ever before—and a social evening which should appeal to all. Special efforts are being made to guarantee a pleasing program for the ladies. From Kaffeeklatsch to dinner, each day will be arranged so as to include numerous activities.

Do plan on being with us. A great and hospitable city is waiting to greet you—an active and friendly committee is anxious to serve you.

Mark your calendar now for—

May 22, 23, 24, 1957

Please remember—early registration can be helpful to you as well as to your host committee.

On behalf of the local committee, the General Convention Committee and the officers of the society, we extend to you a most cordial invitation to attend this outstanding convention.

Sincerely,

H H Bogin

Herman H. Bogin, Chairman
Detroit Convention Committee

(Continued from page 19)

to conceive and develop ideas pertinent to his product. The mechanical drawing produced by him should be recognized for what it is, the sole means of communicating his thoughts and ideas to others involved in manufacturing the product of his creative thought.

The vital importance of this simple fact should be obvious, but in the main it is either not understood or is disregarded for various reasons. Broadly expressed, the major advantage to be found in an engineering drawing of unimpeachable accuracy of design and nomenclature is cost reduction, bearing in mind that many things contribute to effecting economies. Many of the factors involved which contribute to needless extra cost are intangible in nature, that is, they can not usually be found as entries in any accounting procedure.

Numerous impromptu and formal conferences are held to determine what the desired interpretation of drawing data was intended to be; these are costly in many ways and are neither uncommon nor infrequent. Such meetings involving from two to a dozen or more technical people are conducted formally or otherwise in an attempt to resolve such questions as "what meaning was intended in a drawing note" where the note itself was in conflict with other data on the drawing.

Shop people are not supposed to guess, management does not want them to; economic considerations certainly would stigmatize the practice (relatively few individuals guess right 100 percent of the time). The specifying, ordering, design, and making of correct gages and instruments is dependent on the completeness and accuracy of the engineering data.

It is, therefore, essential that engineering information and supplemental engineering standards data be both correct and complete. The gage control organization can play an important part in making personnel aware of the deficiencies of the engineering communications system, and in establishing and implementing improvements and corrections in the system.

In any system involving the use of Product Standards it is essential that all terms be clearly and concisely defined especially the so-called simple terms such as "tolerance." Casual polling of any group of people in the organization will reveal that not all of them, to put it mildly, will state positively that "tolerance is the total variation permitted." So, define the terms your system uses—they are the basic tools with which any "Standards" system is built and operated.

The operating efficiency of a Gage Control program is conditioned by all such factors—both the over-all accuracy of the results achieved, and economical operation are directly affected by them.

The Gage Control group at the Camera Works Plant has played a major role in making their need felt, and in bringing about their adoption and use. In pressing this program, we have been able to observe over a period of time the net results in terms of reduced cost, better product, and an easier, more pleasant way of getting things done right.

BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

STATISTISCHE GUTEUBERWACHUNG (Statistical Quality Control), in German, by Dr.-Ing. Helmar Strauch, Carl Hanser Publishing Company, Munich, Germany, 1956. 176 pages, 128 diagrams, 66 tables. 7 x 9. Reviewed by N. L. Enrick.

This book covers frequency distributions, control charts, and single, double and sequential sampling plans. The many excellent illustrations, and numerous practical examples from a variety of applications, make this a most valuable addition to the quality control literature.

CONTROL ESTADISTICO DE LA CALIDAD, TECNOLOGIA INDUSTRIAL, by E. Blanco Loizelier; published by Graficas Nebrija, S. A.—Ibiza, 11—Madrid 1954; XXIV plus 435 pages. Reviewed by W. D. Baten.

This well written work begins with an interesting history of quality control by statistical methods in countries throughout the world. Following are presentations on frequency distributions, probability, the normal curve, the binomial, the Poisson distribution, control charts for averages, standard deviations, ranges, numbers of defectives, fractions defectives, numbers of defects per unit, together with numerous applications from industry. The entire book contains many well constructed diagrams illustrating different phases of quality control.

Simple, double and sequential acceptance sampling are introduced by ideas pertaining to risks, operating characteristic curves and charts.

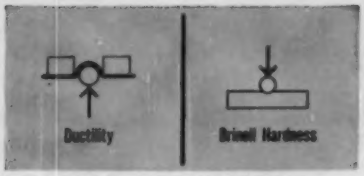
There is a chapter which treats of correlation, analysis of variance, theoretical distributions of several statistics such as Chi square, t, F, Z, and s^2.

The author inserted a rather extensive bibliography. The last part of the book contains auxiliary tables for finding statistical control limits, Dodge-Romig Tables and the MIL-STD—105A Tables. This text will prove very valuable to students and men in industry for it contains the fundamentals of quality control by statistical methods.

EL CONTROL DE LA CALIDAD, by Pedro Mendizábal; published by Artes Gráficas Grijelmo, S. A.—Uribitarte, 4.—Bilbao, Spain, 1951; 106 pages. Reviewed by W. D. Baten.

This small book presents ideas concerning frequency distributions, averages, dispersion, skewness, kurtosis, the normal curve, the binomial distribution and control charts for averages, ranges, standard deviations, fraction defectives, number of defectives, and number of defects per unit.

The author discusses risks in sampling, acceptance sampling and gives tables containing values for finding statistical control limits for control charts which are illustrated by examples.



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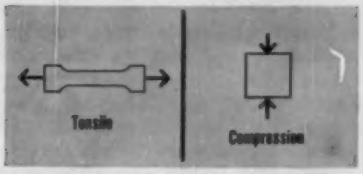

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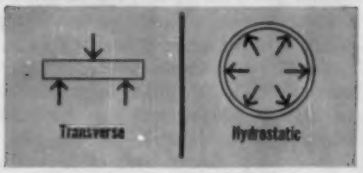

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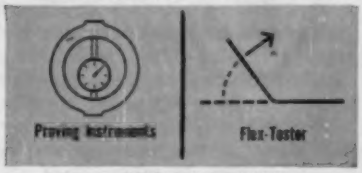

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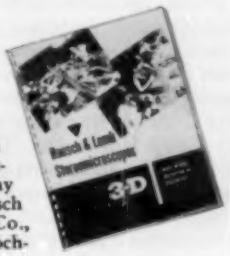

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STEREOMICROSCOPES

What's New?

ROY A. WYLIE, *Editor*

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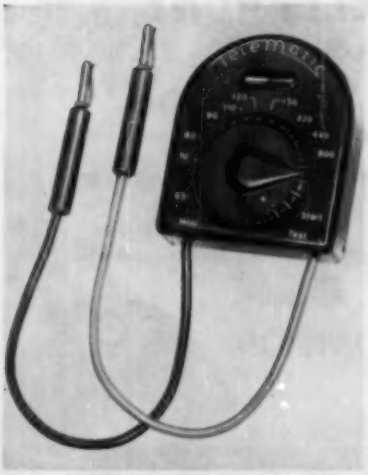


Omega Products, 4700 W. Washington Blvd., Chicago 44, Ill., have introduced a pocket size voltage tester called the Mini-test. It will check unknown voltages from 65 volts to 800 volts, A.C. and D.C. The tester may be used to check whether the voltage is A.C. or D.C., to trace open lines, blown fuses, etc., check continuity of circuits and for trouble-shooting in all electrical appliances and equipment. A new design clip-on lead leaves hands free for work while the tester is being used. The unit is guaranteed for 5 years and the price is $2.95 postpaid.

★ ★ ★

The **Magnaflux Corp.,** 7300 West Lawrence Ave., Chicago 31, Ill., has introduced the Magnatest FW-400 inspection unit for non-magnetic rod, wire, tube, and bar. The new instrument automatically detects such problems as seams, overlapping, diameter changes, inclusions, voids, concentrated porosity, metallurgical variation, and splits. The instrument is designed to cover the whole range of non-magnetic materials from aluminum, brass, and copper to tungsten, austinetic stainless, and titanium in ranges of diameters from 1/64 to 3 inches. The units are designed for either completely automatic, high-speed operation on production lines or hand operation in laboratories. A typical unit can be operated at production speeds in excess of 150 to 300 f.p.m. Such a unit would be operated without any personnel because it could be equipped with automatic signalling and recording devices and works equally well on cut or continuous lengths. The new Magnatest series is designed so that either the absolute or differential types of test can be made. The absolute tests are used whenever changes such as hardness or alloy content must be found. The differential type tests are more common because they negate gradual changes and find only abrupt defects such as seams and lapping. Three different models of the FW-400 series have been designed; one is a vertical floor mount which is best suited for permanent production facilities; another is a console which accommodates several different units and is designed for the maximum flexibility required in research facilities; and the third is a table model which is generally best suited for intermittent usage on a limited number of different materials or sizes.

★ ★ ★

The **Federal Products Corp.,** 1144 Eddy St., Providence 1, R. I., has developed a continuous measuring recording gage to be placed between the feed roll and a punch press so that the strip stock goes through the gage before it reaches the press. By checking the stock continuously and observing the gage meter hand or the recorder chart, the thickness trend of the stock can be followed. The recorder chart provides a permanent record of the thickness variation of each roll of strip stock which can serve as positive evidence of the condition of any particular roll. Also, it can be studied for information regarding the effect that various thicknesses have on the finished stampings. The gage illustrated is adjustable to measure stock from 0.015 to 0.100 inch thick and from 5 to 8 inches wide. The stock passes between two crowned rollers on the gage, the bottom one being the reference contact and the upper one the sensitive or measuring contact. As the stock varies in thickness, the action of the sensitive contact is transferred to an electronic amplifier which moves the meter hand and the pen of the recorder. The gage is made up of stock components for quick assembly and reasonable cost. Other stock items can be added to the basic gage that will enable it to signal the operator with lights or sound signals when bad stock is going through or, as has been done in many cases, the gage can trip a switch to shut off the feeding mechanism when the stock is out-of-tolerance.

★ ★ ★

The Sheffield Corp., Dayton 1, Ohio, has announced a new high-speed electronic gage team consisting of a small electronic pickup cartridge ("Electrojet") for incorporating in new and existing gages and precision instruments and a portable electronic amplifier ("Accutron"). The Electrojet is small, compact, easily mounted. It requires no pickup calibration, being set by locating in setting fixture only. It can be used

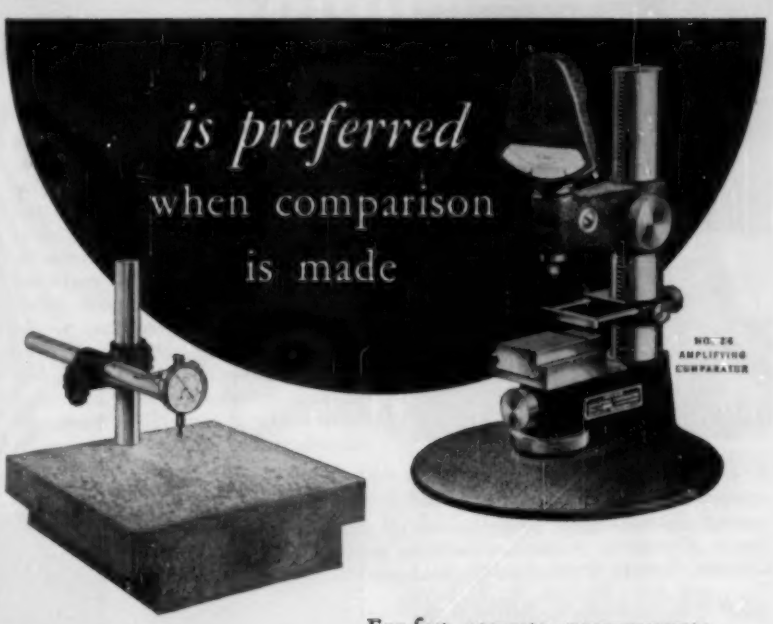
with the full range of Accutron amplifications. The Electrojet is a transducer type gage cartridge ⅜ inch diameter by 1⅞ inches long. The cartridge has a total stylus travel of approximately 0.110 inches. Pretravel is approximately 0.005 inches. Depending upon amplification, effective gaging travel is up to 0.004 inches with an overtravel of approximately 0.100 inches. A positive stop at the end of the plunger overtravel protects the Electrojet against damage. The Accutron is a portable, lightweight electronic amplifier that operates on 110 V., 60 cycle A.C. It is unaffected by line voltage fluctuations from 65 to 150 volts. The amplifier is available with dual amplifications of either 1000/2000; 2500/5000; 5/10,000; 10/20,000; or 20/40,000 to 1. Amplifications within each dual range can be switched from one to another without realignment of the indicating meter mechanism. The 4 inch meter scales are available with graduations over a range of 0.0001 inches for 1000 to 1 amplification to 0.000001 inches for amplifications of 40,000 to 1. An optional outlet may be provided on the Accutron amplifier so that accessory equipment such as classifiers, computors, meter reading recorders, and other instruments may be connected.

★ ★ ★

The Saratoga Scientific Co., Box 488, Saratoga, Calif., has introduced a low cost surface inspection unit called the Micro Surfit. It is designed for determining surface finish in micro inches by comparison or by direct measurement. It can be used on flat surfaces, round surfaces or in holes. In operation, as the probe is stroked across the surface under test, a fine radius sapphire stylus translates minute surface irregularities into an electrical signal which is amplified, corrected and indicated on the meter of the instrument. The meter is calibrated in micro inches. The unit has readings from zero to

AMES

is preferred
when comparison
is made



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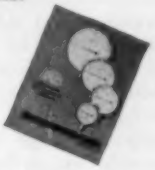

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★ ★ ★

A new type of moisture gauging equipment has been developed in the research laboratory of the E. B. Eddy Paper Company of Hull, Quebec, Canada. **Isotope Products, Inc.,** 1711 Elmwood Ave., Buffalo, N. Y., have been assigned sole rights for the manufacture and distribution of the gauges in the United States. The "Aquatel" moisture gauge measuring system uses the electrical conductivity of paper when an A.C. voltage is applied to it. The resultant signal is fed into a bridge circuit in which the capacity of the sample and the measuring system are cancelled out. An attenuator section allows compensation for temperature, various types of finishes and basis weight variations. The basic principle of measuring A.C. conductivity and the design of the measuring elements results in an insensitivity to both the contact pressure and the presence of static electricity. The range of operation is 3-10 percent moisture content with an operating accuracy of ± 0.25 percent. The AQL laboratory model is used for individual sample measurements. The sample is placed on the measuring electrodes and the percent moisture content is read directly from a meter. The model AQM is designed to scan the entire web of the paper machine at a speed of ten feet per minute, presenting both the integrated average of the sheet moisture content and the moisture profile. The integrated average of the scanning cycle is utilized for automatic control.

★ ★ ★

The **Allegany Instrument Co.,** 1091 Wills Mountain, Cumberland, Md., has introduced two new developments of interest to those who work with data from wire strain transducer systems, used in stress analysis, the measurement of displacement, force, pressure, acceleration, torque, etc. The Type C Calibrator is a universal calibration device which will calibrate any type of wire strain transducer as well as thermocouples and potentiometers. The K-7 Error Computor is a device designed to isolate the magnitude, polarity and location of errors in the whole wire strain transducer system. With these two instruments, measuring systems can be perfected in a matter of days with non-skilled personnel, to a degree that would normally take months and even years of professional-level work. Additional information on both developments is available from the manufacturer.

★ ★ ★

A new low-cost contour and surface projector called the "Magnavisa" has just been announced by **American Optical, Instrument Division,** Buffalo 15, N. Y. The projector is a self-contained portable magnifier suited for inspection and examination of relatively flat objects and small parts, imprinted circuits, fine print of small scale drawings, etc. Two models are available; one enlarges the original material three times; the other, five times. Operation of the instrument is simple. Small objects or flat materials to be examined are placed on a two-way movable platform. The counter-balanced optical head is lowered into contact and the magnified image is projected onto a 4½ × 12 inch viewing screen. Additional areas of the object can be examined by simply moving the platform in the desired directions. Movements of the magnified image on the viewing screen appear in the same directions as the object. Weight is 18 pounds and overall size is 21⅛ × 13¼ × 13¼ inches. The price is $110.00.

★ ★ ★

An automatic precision gear checker developed by **Michigan Tool Co.,** 7171 E. McNichols Rd., Detroit 12, Mich., inspects aircraft and similar types of precision spur gears in about 1/6th the time formerly required. The Model 481 checks for parallelism and tooth spacing and provides a permanent record on the recorder chart. The checker can be used to inspect gears ranging from ¼ to 2¾ inch face width and from ½ to 14 inch diameter. The chart is graduated in increments of 0.0001 inch making it possible to obtain actual readings to even closer limits. The top and bottom recorder pens use different color inks in order to make it simple for even an inexperienced inspector to get the re-

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quired readings without confusion. Checking speed is approximately 5 seconds per tooth. After hand loading of the gear, the cycle is fully automatic. Provisions are made so that any desired number or combination of teeth in any gear may be checked, the balance being omitted. Indexing is controlled by an index plate with a separate plate required for each gear having a different number of teeth. Adjustable indexing drive compensates for size of gear being checked and for different numbers of gear teeth.

★ ★ ★

A Torque Wrench Calibrator has been developed by the **Skidmore Wilhelm Mfg. Co.**, 442 Green Rd., Cleveland, Ohio. Setting and checking of all types of hand torque wrenches is readily accomplished with this bench mounted hydraulic device. A completely self-contained unit, this calibrator requires no piping, wiring or other external connections. It is certified to be accurate within 1 percent of the full scale reading, and may be used to check both right and left hand torque wrenches of flash, snap or dial type. The model shown weighs only 6 pounds, is 7½ inches high, and checks torque from 0 to 30 foot

pounds. Other models are available for torques ranging from a few inch pounds to 2,000 foot pounds.

★ ★ ★

The Magnaglass Mfg. Co., Inc., Fredonia, N. Y., has introduced the "Magnaglass", a 6-power precision magnifier with built-in magnets. This tool consists of a Butyrate transparent housing 1⅛ inches in diameter by 15/16 inches in height into which is sealed a 6-power, non-distortion lens 1⅛ inches in diameter. Protruding from two sides of the housing are small extensions containing powerful permanent Alnico V magnets. The unit comes with a vest pocket size plastic case with snap, for safe keeping when not in use. The magnets grip with a pull that maintains the glass in the exact position, whether vertical, horizontal or upside down until altered. Even heavy vibration will not jar it loose. "Magnaglass" mounts easily to any ferrous metal gage or rule for magnifying fine calibrations. Accurate readings of scales graduated 1/32 inches or less are quickly made without eyestrain. It is also useful in checking scribed lines and centers and in detecting surface defects, cracks and flaws on die surfaces. The price is $3.00 postpaid including the case.

★ ★ ★

A new optical height gage to permit fast measurements of heights up to 61 inches with accuracies of ± 0.000005 inches per inch of height is announced by **Webber Gage Co.**, 12912 Triskett Road, Cleveland 11, Ohio. Known as the Webber Micro-Accurate Optical Height Gage, the new measuring instrument combines Webber Gage Blocks and the Leitz

Measuring Microscope to give speedy accurate surface plate transfer of measurements. The unit is basically a "stack" of gage blocks which are held by spring tension to the known accuracy of ± 0.000005 inches per inch of height. The "stack", which is made up of alternating 0.300 and 0.700 inch blocks, is divided into one-inch measurements by the protrusion of the 0.300 inch blocks beyond the 0.700 inch blocks. By means of a lever operated cam and a vernier adjustment hand wheel, the "stack" of blocks is easily raised and lowered over a range of one inch to obtain fast settings of measurements to 0.000025 inches. These are read in the Leitz optical eye-piece and are measured from the top of the protruding gage blocks corresponding to the inch of height being measured. Measurements are easily and quickly transferred from this point to the

The New
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work or vice versa. The instrument contains no parts which can wear and therefore require servicing. Accuracy always remains the same. The base is a heavy Meehanite casting, firmly supported on three hardened, ground and lapped feet which slide smoothly on the surface plate. The optical system is protected within the base and the gage blocks are supported in a rugged cast iron and aluminum standard. The Micro-Accurate Optical Height Gage is available in four models, measuring to heights of 25, 37, 49 and 61 inches.

★ ★ ★

A new portable electronic non-contact gage is now available from **Industrial Gauges, West Englewood, N. J.** Known as the portable Xact RAY Gauge, this instrument is a miniature edition of the Xact RAY Gauge used by many companies for the measuring and control of thickness, in process, of such products as: plastic sheet and tube, rockwool bats, wall board, plate glass, rubber sheet, cracker dough sheet, paper, cotton batting, felt, and many other products on production lines. The Xact RAY Gauge is a non-contact type employing an X-ray beam whose energy is transmitted through the material being measured. Variations from a predetermined standard weight, density, or thickness, can be held to plus or minus one percent with auxiliary automatic control equipment.

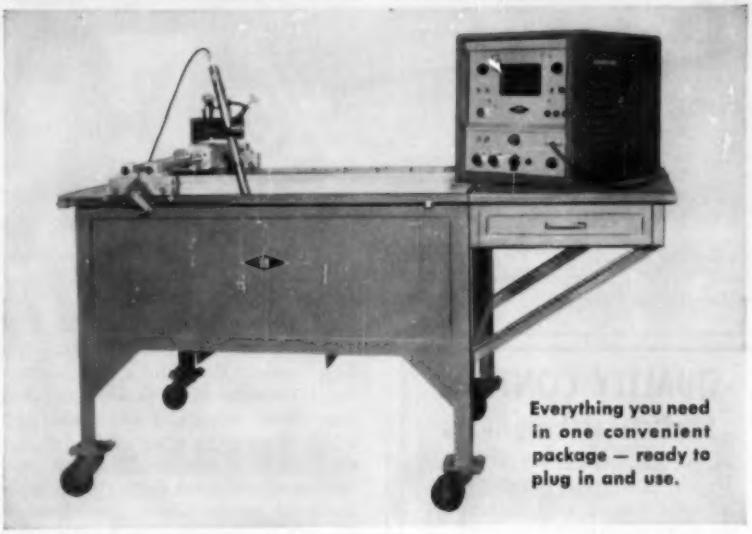
★ ★ ★

Boice Gages, Inc., Hyde Park, N. Y., have released information on a new package of dial bore gages called the TRI-O-SET. The new kit contains three dial bore gages graduated in 0.0001 inches. The three gages cover the entire range of ⅛ to 1 inch and require only ten extensions to cover the entire range. The set, which is packaged in a small, hardwood box with clasps and a handle for convenient carrying, also contains the Boice SETMASTER, an innovation which eliminates the need for master rings for any dimension within a range of 0 to 1 inch.

★ ★ ★

The Sheffield Corp., Dayton 1, Ohio, has redesigned its well known N-7 internal measuring instrument to incorporate a highly accurate electronic gaging system unaffected by line voltage fluctuations. The N-7 Internalcheck is a heavy duty shop and laboratory instrument for inspecting internal diameters of ring-gages and other parts for size, taper, bellmouth and out-of-roundness. Standard capacity is from 0.370 to 12 inch with vertical capacity to 1½ inches. Special gaging arms can be obtained to provide gaging range from 0.240 to 12 inches with vertical capacity to 1 inch. The instrument is available with dual electronic amplification of either 1000/2000; 2500/5000; 5000/10,000 to 1. Amplifications within each dual range can be switched from one to the other without realignment of the indicating meter mechanism. With 5000/10,000 to one amplification direct reading to ten millionths can be made on the

ULTRASONIC INSPECTION



Everything you need in one convenient package — ready to plug in and use.

COMPLETE, THRIFTY PACKAGE for immersed nondestructive testing

Now Curtiss-Wright offers all the benefits of immersion ultrasonic testing of metal without the expense of an assembly of several costly separate units. This new low cost "package" combines in a self-contained single unit the Immerscope — the heart of the system — a four-foot tank, search tube and rack, precision manual manipulator, longitudinal and transverse manual scanning mechanism and a complement of crystals. Here is a complete immersion testing, quality control installation ready to operate, whether in laboratory or light production — a system that can be readily expanded, with only minor investment, for more demanding production applications.

The technique is simple. Metal parts are immersed in water. Ultrasound is applied to penetrate the metal. Defects present will reflect the sound. Those echoes are presented as pips on the cathode ray tube of the Immerscope. Flaw detection is precise and positive.

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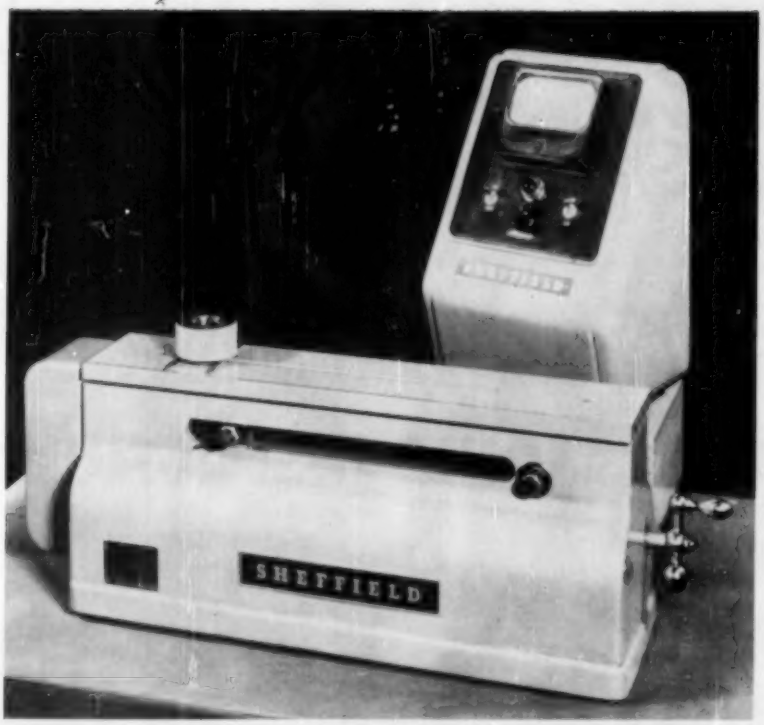

graduated 4 inch zero center equilinear scale. Interpolations to five millionths can be made with accuracy. Both bench and floor type models are manufactured. An auxiliary cooling-off table (12 × 18 inches) for both gage blocks and work is available as an accessory with the floor model. Essentially, the instrument consists of a heavy serrated gage plate, vertically adjustable, on which the workpiece is placed. Gaging contact is provided by two vertical reed mounted gaging arms with diamond points which are elevated into the workpiece. The gaging arms are set to the dimension to be checked with gage blocks. The electronic gaging system has an "Electrojet" transducer type pickup unit connected to a remote "Accutron" amplifier. The pickup unit is actuated by the gaging arm assembly as it is elevated into the workpiece. The "Electrojet" unit requires no pickup calibration and the same unit can be used with all amplifications. The amplifier can be obtained with an optional outlet for connecting a meter reading recorder or other type of instrument.

★ ★ ★

A new insulation tester which audibly indicates and totalizes faults is available from **Peschel Electronics, Inc.**, 9 Garden Street, New Rochelle, N. Y. The Model P-1 counts insulations faults (pinholes) in insulated wire at speeds up to 600 feet per minute—for continuous production use. For use as an insulation continuity tester, the model P-1 features:

- Continuous display of total number of pinholes.
- Continuously adjustable voltage control and panel meter to set voltage for single or multiple coated wire (0-250 V dc).
- Small moistened sponge electrode (uses tap water, not mercury).
- High sensitivity detector operates magnetic counter and buzzer.
- Small test current, 10 microamps, enable use of high resistance electrode circuit, assures reliable operation, no shock hazard, will not harm or mark the finest wire and will detect through 10 megohms.
- Continuously adjustable sensitivity control to desensitize detector to any desired value.

The unit is available in other voltage ranges for use with other electrodes. It may also be used for capacitor testing.

★ ★ ★

The problem of reading a Bevel Protractor easily and accurately has been solved by the George Scherr Co. by adding an adjustable magnifier to their Universal Vernier Bevel Protractor. The measuring dial of the Protractor is "Lustro-Chrome" to eliminate glare. Readings can be taken quickly and efficiently without eye-strain. The tool will measure any angle to 5 minutes and comes regularly with 6 inch blade. Additional accessories available are blades in 8 and 12 inch lengths, acute angle attachment, and a stand. Prices for the standard model with 6 inch blade are $21.50 without magnifier, $22.50 including magnifier. An illustrated circular with detailed instructions on how to read the Universal Bevel Protractor and showing a number of typical applications may be obtained from **George Scherr Co.**, 200 Lafayette Street, New York 12, N. Y.

★ ★ ★

NEW LITERATURE

A brochure describing its new Model 154-B Vapor Fractometer has been published by the Perkin-Elmer Corporation's Instrument Division, at Norwalk, Conn. The model 154-B is operable at higher temperatures than its predecessor, has a more sensitive dual thermal conductivity detector, and has, as standard equipment, a solenoid operated liquid sample collection outlet. The brochure discusses the features and specifications of the new instrument, gives examples of trace analyses possible with it and discusses its use in conjunction with infrared spectroscopy.

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Associated Research, Inc., 3758 W. Belmont Ave., Chicago 18, Ill., has announced a new bulletin on D.C. Hypots. The new instruments, both portable bench type and mobile, described in this bulletin are designed for dielectric strength testing on the production line, in plant maintenance departments, material laboratories, and for use in the field in the testing of wire and cable installations, and their related equipment.

"How to Perform Dye Penetrant Inspections" is the title of a new four-page folder issued recently by Turco Products, Inc., 6135 South Central Ave., Los Angeles 1, Calif. The semi-technical booklet is a manual of established and proved rules for performing inspections by the penetrant process.

Size Control Co., 2500 W. Washington Blvd., Chicago 12, Ill., has announced a new four-page bulletin which will help the gage designer and inspector to "Call out" the proper gage dimensions, when allowances must be made for plating to be applied to piece parts. The bulletin is complete with references to specific sections and paragraphs of H-28 Federal Screw Thread Standards and its 1950 Supplement, plus illustrative charts. Title of the bulletin is "Plating on Screw Threads."

A new eight-page catalog of the Brookfield Synchro-lectric Viscometer line, giving complete information on the various models and accessories available, as well as other information on the general subject of viscosity, is available from Brookfield Engineering Laboratories, Inc., Stoughton 9, Mass.

The Engis Equipment Co., 431 South Dearborn St., Chicago 5, Ill., have prepared reprints of three British papers on the subject of "metrology." They are:

"Large Scale Metrology" by V. B. Hessen, Ministry of Supply.

"Work on Engineering Dimensional Metrology at the National Physical Laboratory" by F. H. Rolt, Superintendent, Metrology Division. N.P.L.

"New Precision Internal Measuring Machine" by C. O. Taylorson and A. Turner, National Physical Laboratory.

Reprints are sent free on request.

A new catalog describing standard production testing machines has been issued by Detroit Testing Machine Co., 9390 Grinnell Ave., Detroit 13, Mich. The catalog's 12 pages contain both picture and information describing ten different models of the company's testers for determining hardness, ductility, tensile compression and transverse strength of metal parts.

General Electric X-Ray Department, Milwaukee 1, Wis., has prepared a 4-page brochure on "X-Ray Diffraction." Basic theory, definitions, analytical advantages and applications in metallurgy, chemistry, mineralogy, physiology, pathology and biology are discussed.

Pratt and Whitney Co., Inc., Charter Oak Blvd., West Hartford 1, Conn., have published two new bulletins covering recent additions to their product line. One covers the Rad-I-Acc continuous non-contacting radiation gages, the other covers the Pratt & Whitney Sigmatic Mechanical Comparator.

The Regal Division of the Beloit Tool Corp. has recently issued new catalogs covering its line of standard and special taps, drills and gages. The new catalogs contain pricing formulas for determining the most economical quantities to purchase. Catalogs may be obtained by contacting Beloit Tool Corp., 12000 Milwaukee Road, Beloit, Wis.

Local Section News

" . . . CAST THEIR SHADOWS BEFORE"

ALLENTOWN -BETHLEHEM The program for the February meeting will be a conducted tour through the Allentown plant of the General Electric Co. This is scheduled for the evening of Feb. 13.

BINGHAMTON The February meeting of the section will be the annual dinner meeting of the Southern Tier Technical and Engineering Society.

BOSTON Professor Grief of the University of Vermont will present the relationship of quality control to marketing research at the Feb. 13 meeting. Don't forget the pre-meeting session at 5:30 at which another statistical test will be discussed in the relaxing atmosphere of the penthouse lounge.

BUFFALO The section will hold a joint dinner meeting with the American Statistical Association at the University of Buffalo on Jan. 28. The speaker will be Major General Leslie E. Simon (ret., USA), director of research and development of the Carborundum Co., Niagara Falls, N. Y. who will speak on "Further observations on initiating a quality control group in an existing organization."

BUZZARDS BAY Welton D. Parker of the Rockbestos Products Corp. in New Haven, Conn., will be main speaker at the Feb. 19 meeting to be held at the Continental Screw Co. in New Bedford. His topic will be "Quality control and assurance by variables."

CHICAGO Calumet Subsection Safety performance, viewed with a statistical quality control approach, will be the topic to be discussed by Carl Jenkins of American Steel Foundaries on Jan 22. Mr. Jenkins' presentation will be a feature of the next meeting to be held at Tiebel's Restaurant, Schererville, Ind.

CHICAGO Fox Valley Subsection An authoritative presentation of the subject "Consumer-vendor relations" will be heard on Jan. 22. ASQC Vice President Leon Bass, manager of quality control for the General Electric Co., gas turbine department of Evandale, Ohio,

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Here are some of its unique features:

• • • Its *Systematic Procedure* provides a preplanned design of experiment with complete directions on where to sample, how to sample, how many observations to take, how to measure, etc. It is a logical, step-by-step method of identifying the major cause of excessive variability. In addition, it saves many hours of conference time by giving detailed specific suggestions for action once the cause has been isolated.

• • • Its *Analytic Technique* is a novel method of separating out and measuring quantitatively the effect of each variable examined. Employing only ranges and making liberal use of precalculated factors, the computations are so simple that they can be learned in an hour by anyone, even though untrained in SQC.

• • • Its "*Pictogram*" graphic method of presenting the results is understandable to engineers and shop people, who have notoriously shied away from answers given in terms of Probability.

• • • Its definition of *Capability* clears up all of the misconceptions that have prevailed on this subject. It answers unequivocally the question of what to do about multi-spindles, out-of-roundness, taper, error of measurement, etc.

• • • Its principle of *Practical Significance* solves the age-old dilemma of what to do when a variable is statistically significant but practically unimportant and vice versa. Statistical significance is painlessly built-in to the procedures, and all measurements and decisions are in terms of the *actual contribution* of the variable to the product variability.

• • • Its principle of *Economic Control* guarantees that the amount of analysis and diagnosis effort will be economically justified. Each analysis goes only far enough to isolate the economically-reducible variable.

• • • Its *Worksheet* is a model of compactness, containing all of the data, information, calculations, analysis and graphic results on a single page. Anyone who can make out an Income Tax can follow the steps with ease.

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will give the talk, featuring actual case histories and illustrations. It will start at 6 pm at Club Arcadia, St. Charles, Ill.

COLUMBUS The January meeting will be held at the Columbus plant of Westinghouse. Frank Caplan, Jr. of the Atomic Fuel Dept. of Westinghouse will talk on "Vendor rating and certification."

CORNING -ELMIRA The Feb. 12 meeting will feature ASQC Vice President Ervin E. Schiesel of the Mattatuck Mfg. Co., Waterbury, Conn., who will speak on "Statistical quality control in cost control."

DALLAS -FORT WORTH Arlington State College again will be the meeting place on Feb. 19 when R. W. Anderson, quality control supervisor of Texas Instruments, will speak on "Statistical problems in transisto.· production." The semiconductor device is produced in such large quantities that many phases of the manufacturing process are fertile fields for statistical evaluation and control for quality.

DAYTON The Feb. 7 meeting will be in the form of a problem clinic. This meeting will be held at the National Cash-Register Co. The panel of moderators will comprise the past chairmen of the section. This type of meeting has not been held for the past few years; therefore we believe this meeting will prove to be informative as well as educational and may solve some of the problems of the day.

DELAWARE The Feb. 7 meeting at the Lord De La Warr Hotel, Wilmington, will feature a talk by Robert W. Kennard of the engineering service division of Du Pont's Engineering Department on the subject "Linear programming." In a brief comparison with the more common statistical techniques the speaker will point out the areas of particular value to the quality control engineer. The talk will not be concerned with the purely mathematical viewpoint but will be more from the viewpoint of the layman in explaining the physical characteristics of example situations.

ERIE On Feb. 15 we are holding our first ladies night program. A program showing some fun with statistics, movies, and the play "Sampling inspection" written by Bonnie Small of Western Electric is planned. A fish-fry and dancing are also planned.

EVANSVILLE -OWENSBORO The January meeting will be held in Owensboro and we are looking forward to having James H. Davidson speak to us on the subject of "Engineering aspects of QC." Mr. Davidson is manager of the statistical methods section of the General Electric Engineering Laboratory.

GEORGIA The Atlanta group will hold its regular monthly meeting on Tuesday night, Jan. 29, in Room 1833 Hurt Bldg., Atlanta. Dr. Robert E. Serfling, M. D., who is chief of the statistical section of the U. S. Public Health Service, Communicable Disease Center, Atlanta, is going to describe some of their work in keeping informed on the prevalence of certain diseases in the U.S. He will relate some of their experience in converting samples into estimates for large population in his talk on "Some problems in applying mathematical theory to epidemics."

GREATER MUSKEGON M. V. Pascavis, program chairman of the section, has just announced that Judson M. Perkins, director of public relations, General Telephone Company of Muskegon, will be guest speaker at the section's annual "Ladies' Night" program. The meeting is scheduled for Feb. 14,

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St. Valentine's Day, which is very apropos considering the presence of the distaff group. Corsages will be in order and the section is looking forward to another pleasant "Ladies' Night."

HARRISBURG The February meeting will be held at the Mount Joy American Legion on Feb. 6. W. J (Bill) Masser will speak to us that evening on "What management expects of the quality control engineer." Some of us, I'm sure, heard Bill give this paper at the Annual Convention in Montreal. Those who didn't hear him will hear a fine talk, and those who did will surely get something worthwhile from hearing it again.

KANSAS CITY On Feb. 13 the section will have a regularly scheduled dinner meeting at the Blue Hills Restaurant. The guest speaker will be J. L. Coburn, QC administrator, Convair, Ft. Worth, Texas. His subject will be "An SQC program that speaks the management language—DOLLARS." A clinic session will precede the dinner.

LOS ANGELES Dr. Paul Stillson, of the Shell Development Co. in Emeryville, Calif., will discuss "Operations research and quality control," at the meeting on Feb. 13.

MICHIGAN Dr. Zenon Szatrowski, senior mathematician of IBM Corp., New York, will discuss "The use of large scale data processors in handling information in industry and business." This meeting will be co-sponsored by the American Statistical Association on Feb. 15 at the Science Hall of Wayne State University in Detroit. The section welcomes Dr. Szatrowski and his advanced presentation.

The American Institute of Chemical Engineers and the Michigan subsection (Bay City, Flint, Midland, Saginaw area) have invited Dr. Sigurd L. Andersen of E. I. Dupont De Nemours & Co., Wilmington, Del., to deliver his paper on "The use of statistical methods in chemical engineering." The session will be conducted at the Dow Auditorium, Midland, on Jan. 24.

Donald M. Spath, General Products Corp., Jackson, Mich., will discuss the various ramifications of "Quality control in a small shop." The Wolverine subsection has reserved the Post Cereals Club House, Battle Creek, for this session on Feb. 1.

MID-HUDSON E. D. Ferrell of Bell Telephone Labs will be the feature speaker at the Feb. 5 meeting to be held in Kingston. Mr. Ferrell will discuss "The control cnart modifications and extensions."

MILWAUKEE W. "Jack" Youden, well-known for his work in experimental design, especially in the field of chemistry, will give a talk to a joint meeting of the section and the Milwaukee Chapter of the American Statistical Association on Jan. 21 at the Stratford Hotel at 7:30 pm.

Bill Golomski, vice chairman of the section, will talk on the Chi-squared test in quality control at the educational session to be held at 5:30 preceding the meeting. The educational sessions are growing in popularity. More attend them than the regularly scheduled talks.

PITTSBURGH For the second dinner meeting of the year, the section will meet at Stouffer's Penn. Ave. Restaurant on Jan. 22 to hear Harry T. Schwan of Methods Engineering Council talk on "Practical applications of linear programming."

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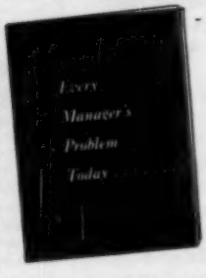

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RACINE The February meeting will bring Fay Carlson of Warner Electric Co. to present his subject "The inspection function." We urge our members and guests to be present at this meeting for with quality control and inspection being as closely related as they are this topic can be of utmost importance to all industry and its operation. Remember the date—Feb. 11; the place—Eagles Hall; the time—7 pm.

ROCHESTER On Feb. 5 the technical sub-group will present Prof. William G. Cochran, professor of biostatistics, John Hopkins University. His topic will be "Combining the information from several experiments."

On Feb. 19 the section and the Rochester Chapter of ASA will meet for the 13th annual all-day clinic which will take the place of the usual monthly meeting.

ST. LOUIS For the January meeting the section has scheduled a plant tour of Owens-Illinois Glass Co., Alton, Ill. which should prove to be very interesting.

SAN DIEGO The topic for the Feb. 11 meeting is "Quality audit" and is in the form of a panel discussion with I. Lundin as moderator. Panel members will be E. S. Barnhardt, Solar; A. S. Billings, Ryan; I. Dagen, Rohr; and R. H. Gilliland of Convair. Each of the members of the panel is manager of quality control of their respective companies. This should prove to be a very interesting meeting.

SEATTLE E. Chiles of Fred Meier, Inc., Portland, Ore., will discuss "Planning for quality control" at the Feb. 12 meeting.

SOUTH BEND -MISHAWAKA The section will hold their annual ladies night on Feb. 21. The dinner will be held at the Club Normandy in Mishawaka. Speaker for the evening will be Prof. Gayle W. McElrath, University of Minnesota. His subject will be "Quality control—woman's oldest weapon." Announcements of the meeting will be mailed to the wives instead of the members. This always seems to increase attendance.

SOUTH TEXAS "Breaking through industry's problem barriers" will be the topic of Dorian Shainin of Rath and Strong at the January meeting. This will be a joint meeting with AICHE with time and place to be announced later.

TOLEDO The January meeting will include a talk on "Quality control in food processing."

TORONTO On Jan. 23 the section will meet in Room 7, Botany Bldg., University of Toronto, to hear members of local companies present their views on sampling inspection.

On Feb. 13 Allan P. Deacon, our District Representative, will talk about the application of statistical quality control in small industries.

WINNEBAGO The meeting for the month of March will be held on Monday, the 11th. The speaker for the dinner meeting will be Larry Neuman, quality control supervisor, Miller Brewing Co.

A training session conducted by one of the members will precede the dinner meeting.

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CHICAGO The next two meetings of the basic educational series, conducted in Room 785 of Roosevelt University, will be held on Feb. 5 and Feb. 15. Messrs. Fred Chiarlotte and Dale Gierke will be co-instructors. The Feb. 15 program will feature "Control charts for attributes" while the following session will describe the use of C-charts and np charts. Starting time is 7:30 pm for both dates.

CINCINNATI The highlight of the year will be presented on Saturday, Jan. 26. The sixth all-day conference will get underway promptly at 9 am with registration of guests at the Netherland Hilton Hotel. The theme of the conference is "Quality control—controlled cost". Chairman Al Evans and his committee set a high requirement for speakers and have compiled an impressive list. John Garrels, assistant general manager of the plastics division of Monsanto Chemical Co., Springfield, Mass., will be the keynote speaker. The luncheon speaker is Gabe Paul, general manager of the Cincinnati Baseball Club. The five workshops will be staffed as follows: general interest—Mel Snow and W. E. Andrus, Jr.; advanced interest—Dorian Shainin and Harry T. Schwan; Administrative applications—R. E. Gruenwald; chemical and process industries—Harry A. Smith and Richard Bingham; electrical and mechanical industries—Allen M. Hall and Harmon S. Bayer.

The educational series will be resumed on Feb. 11 with both an elementary and an advanced course offered in SQC.

COLUMBUS At the request of quality control men in some of our adjacent subsections and in outlying plants the section is planning a training course in basic quality control. Interested parties should contact our chairman, K. Brooks, Ternstedt Division, GMC, Columbus, Ohio.

CORNING -ELMIRA The first of a series of classes on "Basic introduction to statistics and quality control" will be held on Feb. 14 at Corning, N. Y. The course will be introductory and will not require any previous training or experience in QC. It is specifically designed for plant personnel interested in becoming acquainted with the basic principals of statistical quality control in their work. Instructors will be members of the section.

ROCHESTER The 13th annual clinic, sponsored jointly by the section and ASA, begins to look like a big session. It will be held at the new Rochester War Memorial where plenty of space is available for lectures and exhibits. The luncheon and dinner will also be served there. The clinic will consist of four lecture series; each series will include five consecutive lectures and discussions. There will be about 20 exhibits of data processing equipment and electronic and mechanical measuring and gaging equipment.

SOUTH BEND -MISHAWAKA The section's second basic quality control course will start in late January. The first class of 19 has completed its studies. A waiting list of 12 applicants is already registered for the basic class. An advanced QC course will be given at the same time.

SOUTH TEXAS An all-day conference is planned for Feb. 16. The conference is co-sponsored by the Texas Manufacturers' Association. The conference will consist of three sessions: one, a management session; second, on quality control; and third, on statistical methods.

John J. McKetta is scheduled as the luncheon speaker. Mr. McKetta is graduate professor of the school of chemical engineering at the University of Texas and his topic will be "Common sense in engineering."

The fact that an outstanding program is planned is widened by the following list of speakers: Dale Lobsinger, B. J. Manbel, H. B. Epstein, Dr. Paul Rigby, A. R. Burgess, Ben H. Carpenter, Dr. B. S. McArthur, and Dr J. S. Hunter.

WESTERN MASSACHUSETTS The section will begin a series of weekly lectures on operations research on Feb. 19. The six session series will consist of five lectures and a panel group for summary.

WINDSOR The section will present an opportunity for those persons in this area to further their knowledge of the use of SQC at the all-day forum on Saturday Feb. 16. Those attending may take their choice among talks on the use of SQC in the automotive, administrative, consumer-vendor relations, engineering and research, foundry and forging, and food processing fields as well as three sessions devoted to education.

WORCESTER It is planned that on Feb. 5 an all-day symposium will be sponsored by the section and will cover in the broad sense the general subject of quality control. This will be held at the Worcester Polytechnical Institute.

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BOX METHOD OF EXPERIMENTATION FEBRUARY 13-15

Because of the very great demand that has been shown, the Chemical Division will for the third time sponsor a course in the Box method of experimentation. This time the course will be given at the Lamar Hotel, Houston, Texas, on Feb. 13, 14, and 15.

This course was given twice in 1956 under the sponsorship of the Chemical Division at Harvard Business School in May and at the University of Michigan in October. The course outline will be the same as for the two previous courses and instruction will again be in charge of Dr. J. S. Hunter of the American Cyanamid Co. C. T. Shewell, Humble Oil and Refining Co., Baytown, Texas, is chairman of the committee on arrangements for the Houston Course.

NEW YORK QC COURSE

The seventh annual New York quality control course will be held at the Hotel Lexington in New York City from Feb. 22 through Mar. 2.

This intensive eight-day course in SQC will provide instruction in control charts and sampling acceptance procedures, along with practical applications of the methods.

For information concerning the course, contact Ralph E. Wareham and Associates, Consultants on Quality Control, at 122 Orchard Ridge Road, Chappaqua, N. Y.

RUTGERS UNIVERSITY

A basic conference series in statistical quality control will be held at Rutgers University, The State University of New Jersey, in the spring of 1957 in New Brunswick, N. J.

The 1957 series will consist of nine Wednesday afternoon and evening sessions beginning March 20 and concluding May 15.

Afternoon Sessions: 2:15—5:15. Aimed at providing a general understanding of a quality control program, including applications of control charts and the advantages and methods of scientific sampling plans. Practical applications of the modern techniques will be stressed with demonstrations, group discussion, and lectures. Emphasis will be on the applications of the techniques rather than their underlying theory. Case histories of actual plant experiences will be included.

Dinner Sessions: 6:00—9:00. In cooperation with the Metropolitan Section of ASQC, nationally known leaders are scheduled to speak at the dinner meetings. They will discuss general methods and aspects of quality control.

For additional information, write to Dr. Ellis R. Ott, or Dr. Mason E. Wescott, University College, Rutgers University, New Brunswick, N. J.

AAD CONFERENCE

The first annual conference of the Administrative Applications Division is on stage for Friday and Saturday, Feb. 8-9, in the Congress Hotel, Chicago.

Under the guiding hand of general chairman Paul Robert, the program has been arranged to appeal to people with management problems and those who are interested in more efficient methods in management operations.

The luncheon on Friday features the president of Northwestern Bell Telephone Co., A. F. Jacobson, as speaker on the subject "Establishing comparable performance indexes for different departments of our telephone companies." These and nine other interesting presentations are set forth in detail in the brochure now in the mail to all ASQC members and 14,000 other business men.

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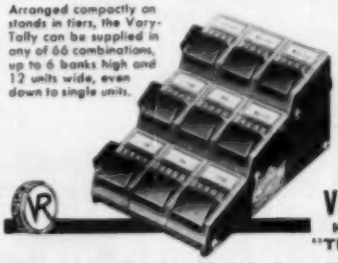

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TEXTILE DIVISION CONFERENCE The seventh annual conference of the Textile Division will be held in Atlanta, Georgia on Feb. 25-27, in the Harrison Hightower Building of the A. French Textile School of the Georgia Institute of Technology.

In connection with the conference, an exhibition of textile testing and quality control instruments has been planned and companies manufacturing and/or marketing such instruments have been invited to participate. The exhibition will be integrated into the technical program and ample time will be allotted on the program to insure everyone in attendance an opportunity to view the exhibits and talk with the various representatives regarding their needs and/or problems along this line.

DIVISIONS

Chemical Division

The division is happy to note an 18 per cent growth in its membership during the first five months of the current fiscal year, a growth which is due in no small part to work of division councilors in promoting the interests of the division in their respective districts.

To maintain liaison with educators in the fields of chemistry and chemical engineering, the division regularly sends to heads of departments its publication, "Chemical Division News." With the fall issue a letter was sent pointing out the growing need for statistical training and listing the companies which have sent persons to the first two sessions of the division's course on the Box method of experimentation. Some very encouraging replies have been received indicating that more and more chemical engineering schools are adding statistics to their curriculum.

The third session of the Box course will be held in Houston, Texas on Feb. 13-15. Dr. J. S. Hunter of American Cyanamid Co. will again be the instructor.

The winter meeting of the division council will be held in Houston on Feb. 15.

SIGNIFICANT DIFFERENCES

Recent changes in the Boston section include: Jim King, formerly with the Doelcam Div. of Minneapolis-Honeywell, has joined the research division of AVCO, in Lawrence, Mass.; Howard Keefe, recently with the Riverside Press, has joined the QC staff of the Hood Rubber Co.; Clarence Tenney, our new membership

Is Your Section "High" or "Low" Man on the Totem Pole?

1. Albany
2. Albuquerque
3. Baltimore
4. Baton Rouge-New Orleans
5. Birmingham
6. Boston
7. Burlington
8. Buzzards Bay
9. Central Illinois
10. Chattanooga
11. Chicago
12. Cincinnati
13. Cleveland
14. Columbus
15. Corning-Elmira
16. Cumberland
17. Dallas-Fort Worth
18. Danville-Sunbury
19. Dayton
20. Denver
21. Erie
22. Georgia
23. Grand Rapids
24. Greater Muskegon
25. Harrisburg
26. Huntsville
27. Indianapolis
28. Iowa
29. Japan
30. Kansas City
31. Lansdale
32. Los Angeles
33. Louisville
34. Memphis
35. Metropolitan
36. Mexico City
37. Michigan
38. Minnesota
39. Montreal
40. Muncie
41. Parkersburg
42. Philadelphia
43. Pittsburgh
44. Pittsfield
45. Portland
46. Rhode Island
47. Richmond, Va.
48. Rockford
49. St. Catharines
50. St. Louis
51. San Antonio
52. San Bernardino
53. San Diego
54. San Francisco
55. Scranton-Wilkes-Barre
56. South Bend-Mishawaka
57. South Texas
58. Syracuse
59. Toronto
60. Tucson
61. Utica
62. Waco
63. Washington
64. Western Massachusetts
65. Western Ontario
66. Wichita
67. Windsor
68. Youngstown

At the left are listed in alphabetical order all of the sections whose membership performance is significantly better or worse than the average. Using each section's membership as reported to the National Headquarters office by Dec. 24, 1956, performance was calculated as a percentage of last year's membership at June 30.

The sections listed at the left are those that fall above or below the 95 percent confidence band. The overall average for the Society this month is 91.6 percent. Worthy of special mention is Harrisburg with a growth of 180 percent; low man on the totem pole was San Antonio with 34.4 percent.

Also of interest is the major reason for the changes between this list and last months'. The society average increased from 80 percent on Oct. 31; consequently sections with insufficient or no increase in membership during the two months covered, now appear on the low side.

Performance significantly better than average:	Performance significantly poorer than average:
2, 6, 12, 14, 15, 16, 18, 19, 21, 24, 25, 26, 29, 30, 32, 33, 34, 35, 36, 39, 42, 43, 47, 48, 50, 53, 54, 57, 59, 63, 64, 65.	1, 3, 4, 5, 7, 8, 9, 10, 11, 13, 17, 20, 22, 23, 27, 28, 31, 37, 38, 40, 41, 44, 45, 46, 49, 51, 52, 55, 56, 58, 60, 61, 62, 66, 67, 68.

chairman, is now located at the Bradley Container Corp. in Maynard, Mass.

Buffalo section member Vic Shelburne, formerly of Spencer Kellog Co., has accepted a position in the quality control department of Carborundum Co., Niagara Falls, N. Y.

Sigmund Zobel, formerly a professor at the University of Buffalo, has accepted a position as a quality control supervisor with Pratt & Letchworth Co., division of Dayton Malleable Corp. Mr. Zobel is a member of the Buffalo section.

Congratulations to two Chicago section members are in order for activities in other technical groups.

Dr. P. H. Randolph, chairman of the membership committee, has recently been elected to the chairmanship of the Chicago section of the Operations Research Society of America.

Dr. Marjorie L. Sutherland, one of the directors of the section, was elected to the membership grade of Fellow in the American Public Health Association at their recent meeting in Atlantic City.

D. C. Brown, educational chairman of the Cincinnati section, has been promoted to supervisor of quality control, engineering subsection, x-ray department, General Electric Co., St. Petersburg, Fla.

Mel Snow, Cincinnati membership chairman, has accepted a new position with Westinghouse Atomic Corp., Pittsburgh, Pa.

The Cincinnati section regrets the loss of these two key men but wishes them well in their new assignments.

Corning-Elmira section member Andrew Dorney has resigned his position as quality control engineer with the Corning Glass Works to accept a similar position with the America Radiator and Standard Sanitary Corp. at their new plant at Plainfield, Conn. Mr. Dorney is currently receiving his preliminary training in New Orleans.

Two active members of the Michigan section have made significant moves. Robert O. Tapler, quality control supervisor of the Chrysler Division has moved to Chrysler's staff quality control. Stanley J. Shimkus, Jr., Chrysler staff quality control, has moved to Chrysler's Trenton engine division as quality control manager.

Dave Archibald, San Diego section, has moved to manager of quality control in the astronautics division of Convair. Lloyd Struckey replaces him in that position at Plant 1, Convair, in San Diego.

Robert G. Fitzgibbons, South Bend-Mishawaka section chairman, has been promoted to supervisor of Bendix Missile Section, reliability department.

John James, member of the Chicago section, has been appointed (Central) quality control manager of the Flexonics Corp., Elgin, Ill.

Michigan section member Fred C. Young, manager of chemical and metallurgical department, quality control office, Ford Motor Co., has been awarded a certificate of appreciation by the Society of Automotive Engineers' technical board for his outstanding contribution to the work of the Society's iron and steel technical committee.

Rutgers, The State University of New Jersey, announced on Nov. 16 the appointment of Harold F. Dodge as an honorary Professor of Statistical Quality Control in its evening college and graduate program of Applied and Mathematical Statistics. He will serve as a consultant and adviser to the University College and Graduate faculties in this program.

Mr. Dodge is Quality Results Engineer at Bell Telephone Laboratories, has authored many articles and studies in acceptance sampling, and is internationally known for his pioneering work in this field. He is a Founding Member and Fellow of the American Society for Quality Control, Chairman of its Standards Committee, a former member of its editorial board for *Industrial Quality Control*, and a Shewhart Medallist of this society. He is chairman of the Technical Committee on Quality Control of Materials of the American Society for Testing Materials, and has been honored as a Marburg Lecturer of that Society.

A graduate of Massachusetts Institute of Technology, Class of 1916, Mr. Dodge also holds an A.M. degree from Columbia University. He joins Dr. Walter A. Shewhart and Dr. Paul S. Olmstead of the Bell Telephone Laboratories as an honorary professor of statistical quality control at Rutgers.

The Atlanta Group will miss Otis L. Brenner, Chief Statistician of the Southern Bell Telephone & Telegraph Company, who passed away on Sunday morning, November 18. He had addressed the Georgia Section, and assisted the Atlanta Group especially in obtaining the use of a conference room for monthly meetings.

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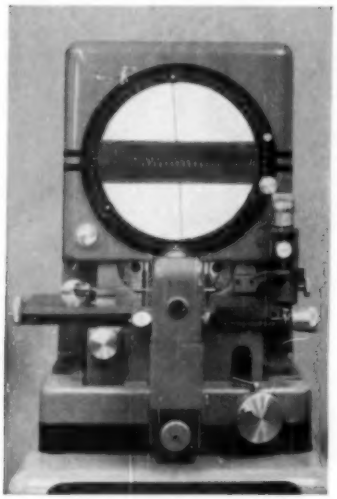
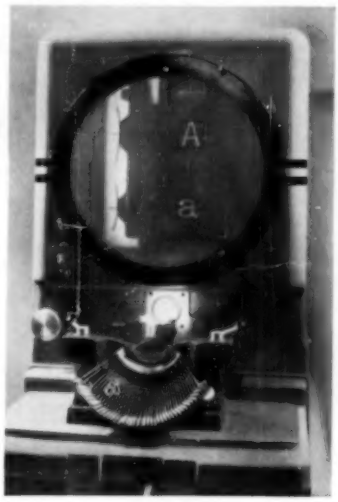
How many places in your plant can projection gaging save time and money?

In the toolroom? Look at this. Prior to adopting projection gaging, a Midwestern manufacturing plant required 725 man-hours monthly to inspect flat drills, taps, special cutters, and circular form tools. Use of a Kodak Contour Projector reduced inspection time 84% to 115 man-hours; cost of the projector was returned in direct labor savings within three months. If you have a heavy inspection load in your toolroom, chances are that optical gaging with Kodak Contour Projectors could effect similar savings for you.

In receiving? Here's the experience of a leading maker of aircraft engines. Their gaging procedure on jet engine blades called for inspecting 11 dimensions (including radii and angles) on the dovetail contour, 14 additional dimensions on the blade root. Using two Kodak Contour Projectors, they checked these pieces at a rate of 150 per hour. And operators required little training. What about your receiving inspection department? Couldn't a fast, highly accurate method of inspecting all sorts of parts with multiple dimensions and complex shapes help prevent bottlenecks?



In production? A lot of people don't think of optical gaging in terms of production inspection. A typewriter maker did. To check the alignment of type bars to ±.0002″, they placed a Kodak Contour Projector next to the soldering jigs on which bars are mounted on their arms. Catching errors at this point and correcting the jigs reduced alignment time in final assembly 25%. Install Kodak Contour Projectors next to production equipment and you have a fast, continuing check that insures machine settings are correct. That's a good way to keep scrap costs down and quality up.



In final inspection? Ever have a part that was almost impossible to inspect accurately and completely? A leading West Coast electronics manufacturer did. They had to check the precise pitch of a fine wire helix mounted in its glass tube. "Without the Kodak Contour Projector," the company reported, "it would not be practical to make the measurements necessary to get a satisfactory instrument." Many times optical gaging on a Kodak Contour Projector lets you measure small or easily distorted parts with a simplicity and accuracy you can't achieve by other methods.

WHATEVER your inspection or measuring problem, there's a Kodak Contour Projector to do the work, from the bench-type Model 8 to the big Model 30 with its 30-inch screen and large part capacity.

To find out more about how optical gaging can save you time and money, improve accuracy, send for the booklet, "Projection Gaging with Kodak Contour Projectors." Write *Special Products Sales Division.*

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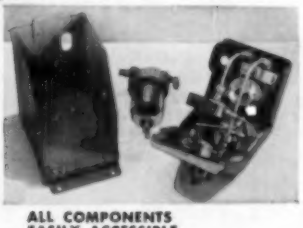

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